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THE JOURNAL OF THE AMERICAN WELDING SOCIETY PUBLISHED FOR THE ADVANCEMENT OF THE SCIENCE AND ART OF WELDING

VOLUME 16 JANUARY 1937 NUMBER 1

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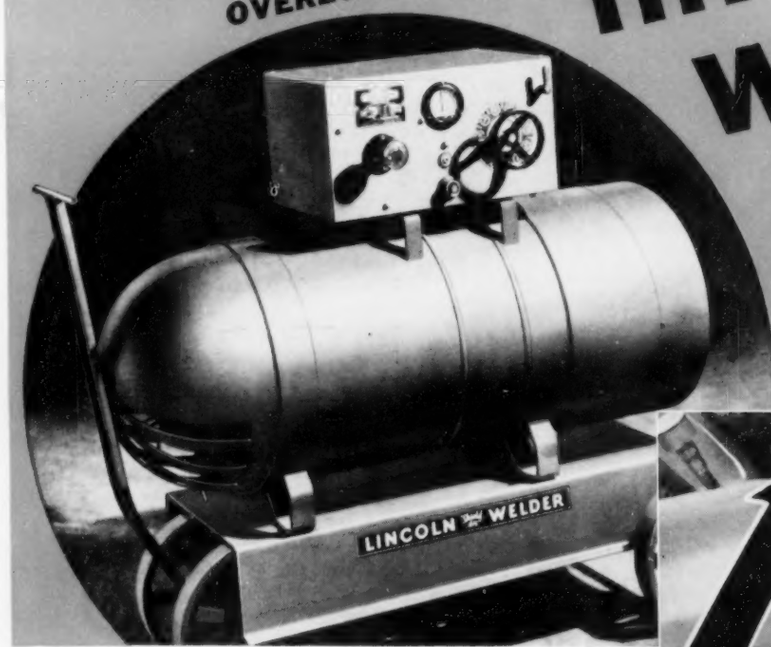

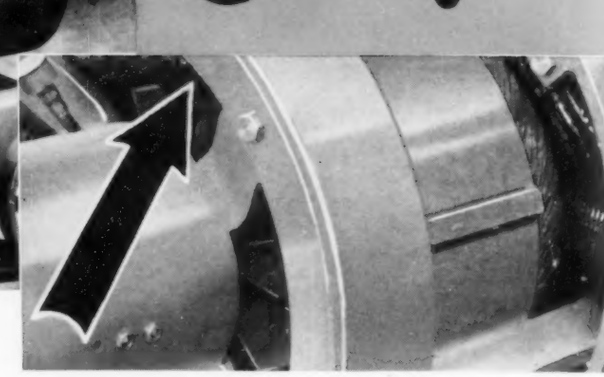

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Designs Involving Fillet Welds

By CYRIL D. JENSEN†

THE design of connections utilizing fillet welds, as explained by Jennings in his paper on "Welded Design" in the October 1936 JOURNAL OF THE AMERICAN WELDING SOCIETY, can be simplified if the conception of stress in a fillet weld be changed from lb. per sq. in. to lb. per linear inch of weld. For instance, the much-used allowable shearing stress of 11,300 lb. per sq. in. can readily be converted to lb. per inch, giving a value of 1000 lb. per eighth inch of leg for the standard 45° fillet weld. Or, if coated electrodes are used, the permissible stress may be on the order of 1250 lb. per inch, giving 3750 lb. per inch for a $^3/_8$-inch fillet weld.

For situations where welds do not conform to the standard 45° fillet the following is suggested for determining the allowable stress per inch of weld.

1. When leg "*a*" does not equal leg "*b*" (Fig. 1).
   (*a*) If load is in direction of the longer leg (Fig. 1*A*), the average of "*a*" and "*b*"* may be used to determine the size of equivalent 45° standard fillet. Thus, if it seems desirable to design a $^3/_8$- by $^1/_2$-inch weld as in Fig. 1*A* the working load would be 3500 lb. per inch on the basis of 1000 lb. per eighth or 4375 lb. per inch on the basis of 1250 lb. per eighth.
   (*b*) If load is in the direction of the shorter leg (Fig. 1*B*) the shorter leg only is used to determine the size of equivalent 45° fillet.

2. When weld is concave in profile (Fig. 1*C*) the throat section governs. Inscribe on typical cross section a triangular fillet and from that determine the allowable load per inch of weld. Incidentally this weld will have a high factor of safety but there seems no better way to evaluate it than as described.

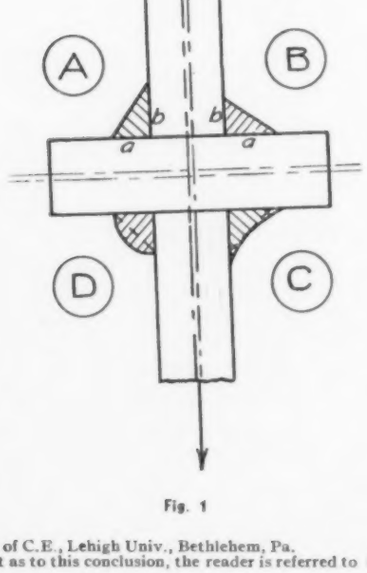


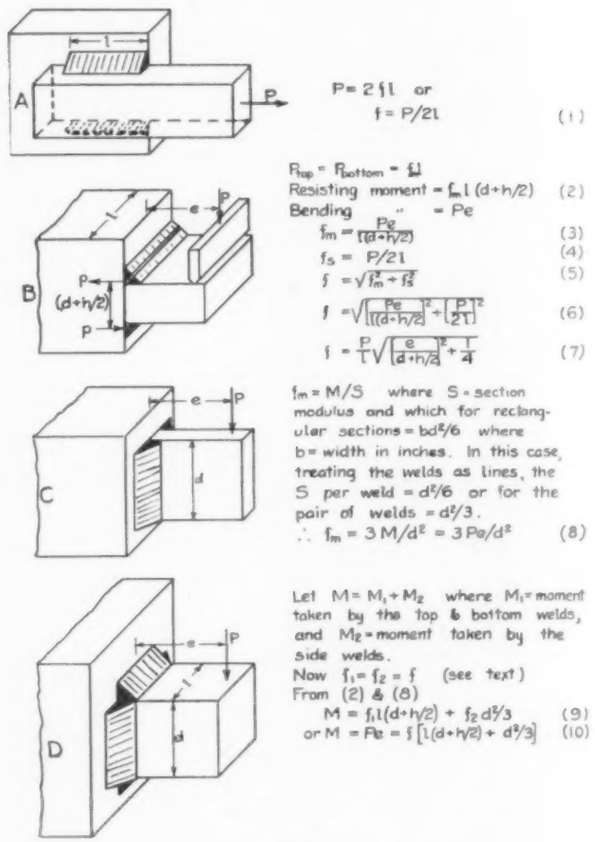
Fig. 1

3. When weld is convex in profile (Fig. 1*D*) the leg distances govern. As for the concave fillets, inscribe a triangular fillet and from that determine the allowable load per inch of weld.

The stresses quoted above apply for quiescent loads. When loads are repeated with complete reversal of stress the allowable load per inch of weld should be about a third of that permitted for quiescent loads as explained by Jennings in greater detail. Only covered electrodes should be permitted on such structures.

Investigation has proved that the load may be applied on a linear inch of weld in any direction whatsoever,[3] and the ultimate load (provided no bending action exists) will always equal or exceed the value obtained by pulling in the direction of the length of the weld, which is the direction used in obtaining the safe working stresses. In other words, the value of 3000 lb. per inch for a $^3/_8$-in. fillet weld (or 3750 for coated electrodes) is safe regardless of the direction of the applied load.

The discussion up to this point has dealt with the problem of determining the safe load per linear inch of weld. There now follows a number of examples illustrating the use of the "linear inch" in design problems. The abbreviations used in the examples are as follows.



$P = 2fl$ or $f = P/2l$ (1)

$P_{top} = P_{bottom} = fl$

Resisting moment $= f_m l\,(d+h/2)$ (2)

Bending " $= Pe$

$f_m = \frac{Pe}{l(d+h/2)}$ (3)

$f_s = P/2l$ (4)

$f = \sqrt{f_m^2 + f_s^2}$ (5)

$f = \sqrt{\left[\frac{Pe}{l(d+h/2)}\right]^2 + \left[\frac{P}{2l}\right]^2}$ (6)

$f = \frac{P}{l}\sqrt{\left[\frac{e}{d+h/2}\right]^2 + \frac{1}{4}}$ (7)

$f_m = M/S$ where S = section modulus and which for rectangular sections $= bd^2/6$ where b = width in inches. In this case, treating the welds as lines, the S per weld $= d^2/6$ or for the pair of welds $= d^2/3$.

$\therefore f_m = 3M/d^2 = 3Pe/d^2$ (8)

Let $M = M_1 + M_2$ where M_1 = moment taken by the top & bottom welds, and M_2 = moment taken by the side welds.

Now $f_1 = f_2 = f$ (see text)

From (2) & (8)

$M = f_1 l(d+h/2) + f_2 d^2/3$ (9)

or $M = Pe = f\left[l(d+h/2) + d^2/3\right]$ (10)

Fig. 2

† Asst. Prof. of C.E., Lehigh Univ., Bethlehem, Pa.

* If in doubt as to this conclusion, the reader is referred to (9) in the bibliography.

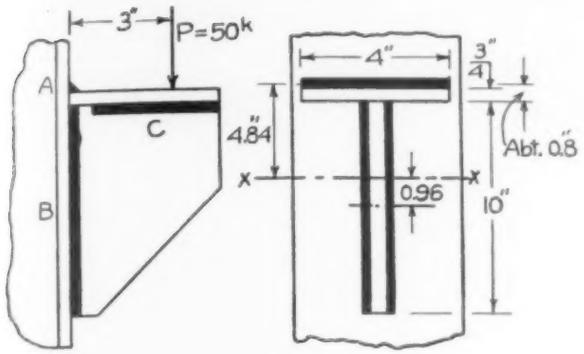


Fig. 3

f = permitted stress in lb. per inch of weld
f_m = weld stress due to bending moment
f_s = weld stress due to shear
l = length of weld in inches
P = applied load in lb.
e = moment arm in inches
h = length of one leg of a fillet weld.

In Fig. 2*A*, $P = 2fl$. The designer should check the plates joined for over-design, and, if the condition exists in both plates, he should similarly over-design the welds. For instance, let $P = 30{,}000$ lb.; then if $^3/_8$-in. welds are used at 3750 lb. per inch, $l = 30{,}000/7500 = 4$ inches. Now a $4 \times {}^1/_2$ inch plate may be selected having an area of 2 sq. in. The plate has a capacity of $2 \times 18{,}000$ or 36,000 lb. which means that the weld is a weak link. It would be advisable, therefore, to add one inch of weld to each length, giving a safe load on the weld slightly greater than that for the parts joined.

In Fig. 2*B*, let "p" be the load carried by each of the two welds shown. The moment arm between these two forces is more nearly $d + h/2$ than the $d + h$ given by Jennings in his Fig. 12. (It would seem better to drop the $h/2$ for an approximate solution, realizing that to do so is on the safe side.) The remainder of the solution is clearly given in the figure. If the moment arm "e" is greater than two times $(d + h/2)$ the shear component may be dropped and formula (2) applies, replacing f_m by f.

The complete solution of the problem in Fig. 2*C* is given in the figure; however, in case these welds are to be subjected to repetition of stress, considerable caution should be exercised as there is some dissension regarding the distribution of stress in the welds (straight line distribution of stress was assumed). Schreiner,[4] in an investigation involving slowly applied loads finds the welds amply safe according to formula (7), whereas Shedd[5] believes that concentrations exist at the top and bottom ends of the welds and that these would be dangerous under repetitive loadings. An investigation made by Hollister[6] using polarized light on transparent models indirectly confirms Shedd's theory. Schreiner's work proves that straight line distribution of stress may be accepted as safe for quiescent loads. (In fact Schreiner advocates basing the design formula on a rectangular distribution of stress.) However, when repetition of load obtains, an added factor of safety should be applied, "a factor of ignorance" so to speak.

In combining top welds with side welds as in Fig. 2*D* the approach is practically the same as that by Jennings. Let $M = M_1 + M_2$, where M_1 is the moment taken by the top and bottom welds, and M_2 is the moment taken by the side welds. Now $f_1 = f_2$ since the distances from the neutral axis to the extreme fibers for the two pairs of welds are very nearly the same. The shearing stresses on the welds may be disregarded unless l exceeds, and e is less than d. The resulting formula is (10) in Fig. 2*D*. In case the arm "e" is so short that shearing loads enter the computation, the writer prefers to treat the shear as uniformly distributed (see Hollister's report). Then in (10) f becomes f_m

$$\text{also } f_s = P/(2l + 2d)$$

$$\text{and } f = \sqrt{f_m^2 + f_s^2}$$

When lines of weld forming a T are subjected to bending,[7,8] as in the bracket in Fig. 3 it is first necessary to find the center of gravity axis, x-x, of the lines of welds. This can be done easily by taking moments about the top weld line. (Welds A and B together resist the bending moment of 150,000 lb. inches. Weld C serves only to join the top plate to the web plate and does not enter into this calculation.)

$$\frac{2 \times 10(5 + 0.8)}{(2 \times 10) + 4} = 4.84 \text{ inches}$$

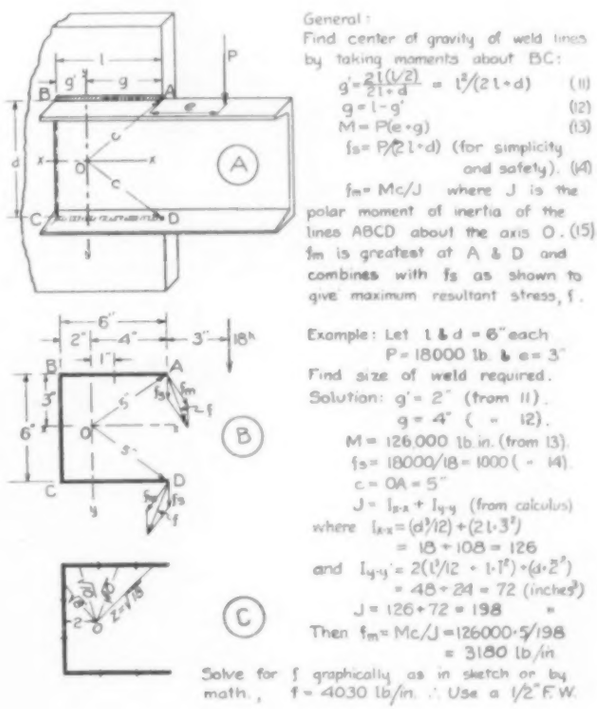
Now as in the previous example,

$$f = M/S$$

but in this case S must be worked out in detail. The value "c" will be the distance from the x-x axis up to the top weld since tearing of the top weld is the concern.

$$S = \frac{I}{c} = \frac{1}{4.84}\left[2\left(\frac{10^3}{12} + 10 \times 0.96^2\right) + \left(4 \times 4.84^2\right)\right]$$
$$= 57.6 \text{ (inches}^2\text{)}$$

Therefore, f_m (for the top weld) $= 150{,}000/57.6 = 2600$ lb. per inch. If shear is assumed uniformly distributed throughout the welds A and B, the weld A is subjected to a horizontal force of f_m or 2600 lb. per inch and to a vertical force of f_s or 2080 lb. per inch. Combining f_m and



General:
Find center of gravity of weld lines by taking moments about BC:
$g' = \frac{2l(l/2)}{2l + d} = l^2/(2l + d)$ (11)
$g = l - g'$ (12)
$M = P(e + g)$ (13)
$f_s = P/(2l + d)$ (for simplicity and safety). (14)
$f_m = Mc/J$ where J is the polar moment of inertia of the lines ABCD about the axis O. (15)
f_m is greatest at A & D and combines with f_s as shown to give maximum resultant stress, f.

Example: Let l & d = 6" each
P = 18000 lb. & e = 3"
Find size of weld required.
Solution: g' = 2" (from 11).
g = 4" (" 12).
M = 126,000 lb.in. (from 13).
f_s = 18000/18 = 1000 (" 14).
c = OA = 5"
$J = I_{x\text{-}x} + I_{y\text{-}y}$ (from calculus)
where $I_{x\text{-}x} = (d^3/12) + (2l \cdot 3^2)$
$= 18 + 108 = 126$
and $I_{y\text{-}y}' = 2(l^3/12 + l \cdot l^2) + (d \cdot 2^2)$
$= 48 + 24 = 72$ (inches^3)
$J = 126 + 72 = 198$ "
Then $f_m = Mc/J = 126000 \cdot 5/198$
$= 3180$ lb./in
Solve for f graphically as in sketch or by math., $f = 4030$ lb./in. ∴ Use a 1/2" F.W.

Fig. 4

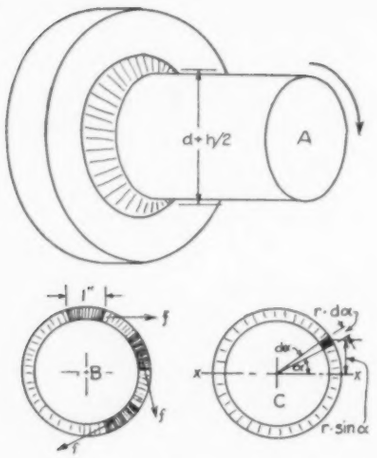


Fig. 5

f_s to find the hypotenuse of the triangle, $f = \sqrt{f_m^2 + f_s^2}$ = 3330 lb. per inch. A $^3/_8$-inch fillet weld is satisfactory if coated electrodes are used.

When a combination of welds as in Fig. 4 is subjected to bending action a rather nice solution may be obtained by following a method outlined by Odd Albert.[2] If this solution, which is given in detail in Fig. 4, appears too complicated an approximate solution may be used to find the polar moment of inertia from the general expression, $J = \Sigma\ da.z.^2$ By dividing the lines of welds into short sections or increments and finding the distance (z) from the midpoint of each section to point 0 as in Fig. 4C, the summing up of the $da.z^2$ units may readily be done. If 2-inch sections are used as in the example, J (by the approximate solution) is equal to $2[(2 \times 18) + (2 \times 10) + (2 \times 10) + (2 \times 8)] + (2 \times 4) = 192$ (instead of 198 by the exact solution). The error is about 3%. The remaining portion of the solution is the same as in the figure.

Shafts of steel are sometimes welded to plates as shown in Fig. 5A, and the combination may be subjected to either twisting or bending. In this case the problem of twisting is the simpler and is given first. In Fig. 5B, consider 1-inch increments of weld and let f be the allowable load on each. Then the safe resisting moment of each inch of weld is equal to $0.5f\ (d + h/2)$ and the total resisting moment is equal to the circumference times this value or,

$$T = 0.5\pi f(d + h/2)^2 \quad \text{(for twisting)} \qquad (16)$$

For shafts subjected to bending the problem is more complicated unless one remembers that I_{z-z} (Fig. 5C) will be just half of the polar moment of inertia, which was practically found in the preceding problem. Since the "c" values will be the same in the formulas, $M = fI/c$ (for bending) and $T = fJ/c$ (for twisting), then $I/c = 0.5J/c$. This latter value was found in (16) to equal $0.5\pi(d + h/2)^2$ and therefore $I/c = 0.25\ (d + h/2)^2$ and

$$M = 0.25\pi f(d + h/2)^2 \text{ (for bending)} \qquad (17)$$

As a check on this work, I_{z-z} of the circular weld line is worked out by calculus as follows.

$$I_{z-z} = \Sigma\, da.y^2 \text{ (general)}$$

$$= \int (r.da)(r.\sin\alpha)^2$$

$$= r^3 \int_0^{2\pi} \sin\alpha.da$$

$$= \pi r^3 \quad \text{where } r = c = 0.5(d + h/2)$$

Resisting moment $= fI/c = \pi f r^3/c = 0.25\pi f(d + h/2)^2$ which checks (17).

From the foregoing examples it is hoped that a clear picture is given of the speed and ease with which designs may be effected, especially if the $h/2$ value be dropped as suggested in the text. To the writer it appears so much simpler to use the linear inch of weld in designing fillet welded joints that it seems that the other method, the lb. per sq. in. method should be relegated to the research men and specification writers.

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Corrosion of Welds

By C. J. HOLSLAG*

In my experience, I have never seen welding corrode. My experience goes back to way before the War. I was welding supervisor for the New York Central Railroad for eleven years previous to 1917, and I can find welds made around the Railroad especially in buildings some of them in round houses where engine smoke and very bad ventilation conditions exist and in each and every case the welds are intact although in some cases the original metal is very badly corroded. About 25 years ago the transmission line and signal bridge poles of the New York Central Railroad along the Hudson River, which is tide water, were badly corroded at the base from spray and these poles were welded. Recent examination shows that the welds are intact; in fact, about 1922 it was noticed that the welds were good and the original metal was corroded; the entire bases were welded as being the best solution to the problem.

During the War Commander Knox of the Navy who was on the Welding Committee of the United States Shipping Board, together with the writer, welded a great many test pieces on battleship cruisers. He finally took them off twelve years later because upon yearly examination no corrosion developed.

In 1920 when the building at this address was erected, it was entirely welded and the welds are absolutely intact. We recently had to remove a section to where we enlarged the rear of the building and the welds are perfect although there was pitting everywhere in the parent metal. I am saving a section of some of the joints and columns removed as a monument to lack of corrosion. In 1922 when we built our house in South Orange we welded some ornamental poles in the yard and the poles themselves are just about gone but the welds are exactly as originally made, the handwriting of the welder being just as plainly visible as the tool marks of a recently machined piece.

I have seen many boiler tubes and boiler shells replaced that were originally repaired by welding and in each case the welds were perfect although the rest of the metal had either pitted thin or leaked. And vice versa, there are thousands of thin places built up by welding that have never had to be replaced again.

The whole summation is that I am certain from twenty-eight years experience in welding that there is no corrosion. I recently assured some engineers who were considering steel facing a dam that corrosion of the welds would not be present.

* President, Electric Arc Cutting & Welding Co.

The Magnaflux Inspection of Pressure Vessel Welds*

By JOSEPH W. YANT†

THE application of the magnaflux test to pressure vessel welds is a rather recent development, it being only within the last 18 months that Oil Companies have specified magnaflux testing on certain classes of this work. The company with which the writer is associated first applied this method of testing to the alloy welds of vessels lined with ferritic stainless steel in which the liner was fastened to the carbon steel backing plate by a resistance weld, an arc weld or a combination of both. Subsequently magnafluxing was used as a final test after the hydrostatic test for all welds of vessels not X-rayed and for all welds of vessels X-rayed before stress-relieving. Where vessels have been X-rayed after stress-relieving the magnaflux test has been applied only to those welds not possible to X-ray, such as nozzle, manway and supporting lug welds.

A pressure vessel to be magnaflux tested must first be magnetized. Therefore, this test is not applicable to welds of the non-magnetic austenitic type steels such as the 18% Cr, 8% Ni. Vessels may be either completely or locally magnetized, depending somewhat on preference or on the amount of testing to be done. Where vessels are large and have many feet of welded seam to be tested, or where a vessel is alloy lined for corrosion resistance and the entire inner surface is to be tested, magnetizing the whole vessel at once is probably most convenient for the inspector. Where only a small amount of welded joint is to be tested, local magnetization by either of two methods may be quicker. However, some manufacturers prefer to use local magnetization even though large areas are to be tested. Where large areas are tested by either complete or local magnetization, they should be mapped so that no portion will escape inspection.

A vessel to be entirely magnetized is wrapped with cable and to perform a thorough job of testing it must be tested separately with a girth wrapping and with a longitudinal wrapping. Welder's cable is satisfactory. The first step, then, is the winding of anywhere from six to fourteen turns of cable around the girth of a vessel at the center and connecting the two ends of the cable to the terminals of a welding generator capable of producing a current of at least 300 amperes. The amount of current to be used may be gaged roughly by determining whether the ends of the vessel are magnetized enough to attract small pieces of steel. On a vessel of $1^9/_{16}$ inch wall thickness, 8 feet diameter and 40 feet long, wrapped with eight turns of cable, 300 ampere current has produced satisfactory magnetization.

When the vessel is magnetized the test is performed by sprinkling magnaflux powder lightly over the weld and striking the plate alongside the weld with a hammer to cause the powder to arrange itself and line up over any defects that may be present. This powder is finely divided iron, mixed with some other ingredients. Where there is a crack in a magnetized vessel the powder will attempt to bridge the gap between the two edges of the crack. Should the vessel be rather strongly magnetized the powder may line up on the high spots of the ripples of a cover bead or at sharp changes of contour but it will be found that a light jet of air will remove such lines. If a crack is present, even a strong jet of air will not remove the powder line.

If the surface of a weld to be tested slopes too much the magnaflux powder will slide off and will not give a good indication. Thus, it becomes necessary, when testing circumferential seams, to roll a vessel from time to time as the testing progresses and test only that portion of the seam from which powder will not slide off too easily.

When a vessel is magnetized by energized cables wrapped around the circumference, the path of the magnetic flux is parallel to the longitudinal axis and weld defects such as cracks perpendicular to the flux path will cause the greatest magnetic disturbance and will show powder lines more readily than defects parallel with the flux path. Weld cracks running parallel with the flux path, that is perpendicular to the cables, may not show at all. Thus, to be sure that dangerous weld imperfections are not missed, cable must be wrapped around the vessel a second time—this time in a longitudinal direction.

In longitudinal cable winding, nozzles in each head are an advantage since the cable is then led in a nozzle at one end, out the nozzle at the other end, and carried back along the outside of the shell and again inserted through the entrance nozzle until six or eight turns are made. The cable ends are again attached to the terminals of a welding generator. When the cables are energized, all welds must be tested again. Wrapping cables longitudinally is a more efficient way of magnetizing a vessel since the magnetic flux has a complete metallic path around the circumference as compared with the air path from end to end of a girth wrapped vessel.

If a vessel does not have a nozzle in the top head the cable may be brought out a side nozzle or manway near the top. The vessel will not be magnetized beyond the cables and a portable means of magnetization such as electro-magnets must be used to test the remainder. If a top head nozzle is too small to accommodate the sufficient number of turns of cable, a set of bus bars may sometimes be made up, each one insulated from the other and the assembly inserted through the nozzle. The individual turns of cable may each be attached inside and out to a separate bar and the circuit made in that manner.

When a vessel is small or when the amount of welding to be tested does not justify magnetizing the whole assembly, a pair of portable electro-magnets or a single electro-magnet with a U shaped core may be used to magnetize small areas at a time. About a foot of seam at a time should be tested, once with the magnets straddling the seam and once with the magnets about a foot

† Standard Oil Company of Indiana.

* Paper presented on Oct. 23, 1936 at A. S. M. E. Symposium, Cleveland, Ohio.

apart on the seam. The procedure should locate either longitudinal or transverse cracks in a weld. The electromagnets will be found rather burdensome to handle due to their weight if much welding is to be tested.

Another means of local magnetization of vessel is by passing a heavy current through the area to be tested. This may be accomplished by an apparatus having two metal fingers set in an insulating handle, the fingers having no contact with each other. Lead wires from the source of power are attached to each finger. The contact points are pressed on the surface of a vessel and a heavy current turned on. The area between the points of contact is magnetized by the flow of current and the magnaflux test is made while the current is on.

The type of defect indicated most readily by the magnaflux test is a crack which extends to the surface of the weld. Even the shallowest crack or checks will show a powder line. In numerous cases in welds of an air hardening steel, the radiographs of a given section of weld showed no defects, but in the same section of welded seam a powder line appeared on the magnaflux test. The cause of the powder line was determined by chipping and in each instance the cause was found to be a surface crack about $^1/_{64}$ inch deep. Since the total thickness of the weld was about $1^3/_4$ inch, the cracks were too shallow to show on the radiographs. These cracks, without the aid of the magnaflux test, were invisible although some could be seen with a magnifying glass.

More serious defects have been found in welds around nozzles and manways. In one case the outside fillet weld around a 20-inch manway was being tested. This manway was of the integral reinforcing pad, extended neck type. Previous to the magnaflux test, an air pressure of 100 lb., indicated by a gage installed on the pad diametrically opposite the air connection, had been introduced between the vessel plate and the nozzle pad, the welds had been painted with soap solution and no leaks had been found. The outside fillet around the manway pad had been built up, using circumferential beads of weld and, in magnafluxing, the powder tended to concentrate in the crevasses between the beads, but it could be blown away easily, indicating that a sharp change in section, and not a crack, was causing the powder lines. At one location in the fillet a powder line 1 inch long could not be removed with an air jet and it was noted that the line crossed one bead of weld. Exploration of the cause of this 1-inch long powder line showed that the outside fillet weld was cracked three quarters of the distance around the manway although the crack had come to the surface only at the location of the powder line.

The fact that weld cracks, which extend perpendicular to the wrapping cables may not be found, is shown by the following example. While magnaflux testing a vessel that had not been X-rayed, the cables were first wrapped circumferentially and several transverse cracks were found in two girth seams. When the same seams were later tested with the cables wrapped longitudinally many more transverse cracks were found. These cracks were produced when a three section assembly of the vessel was rerounded in a power roll during extremely cold weather.

An unexpected location of cracks in a pressure vessel was found while the head seams of a $^9/_{16}$-inch thick wall drum were being tested. The powder falling on the tangential section of the head formed a multitude of lines parallel to the axis of the vessel around nearly two thirds the circumference of each head. When the powder was blown away very fine lines could be seen on the surface of the oxide scale. The scale was ground away and it was found that the metal itself was also checked. About $^1/_{16}$ inch of metal had to be removed to eliminate these checks or cracks which had probably been produced in the head forming operation. Had the magnaflux powder not fallen on these heads more or less by chance, this vessel would have left the shop containing many cracks which were probably of little consequence at the time but might have grown into something more dangerous in service.

While some users of the magnaflux test have reported finding sub-surface defects repeatedly in other classes of work by this method of testing, the efficacy of the magnaflux test for detecting sub-surface defects in pressure vessel welds is, in the writer's opinion, open to question. With the exception of several cases of sub-surface porosity which will be discussed later, the writer has never found any sub-surface defects by this method of testing, either during routine inspections or laboratory investigations. Most of the welds covered by the routine inspections had been X-rayed and repaired before the magnaflux test and, therefore, were not expected to reveal any defects of importance other than cracks which might have developed subsequent to the X-raying. Other pressure vessel welds (notably around nozzles and in Class 2 work) were not X-rayed at any time, however, and in all probability contained some sub-surface defects when magnafluxed. The specimens investigated in the laboratory were welds which were known to contain such defects as slag inclusions and unfused lip edges. These defects, however, could not be located by magnafluxing.

It is believed that better testing conditions would prevail if the cover beads on welded seams were removed and nozzle and manway fillets were chipped smooth. If this procedure did nothing else, it would remove the cause of false indications such as powder lining up in grooves between beads on nozzle fillets or powder lines forming on the ripples and ridges of a seam cover bead. Furthermore, it might make the detection of sub-surface defects more certain.

Strangely enough, the only clear cut detection of sub-surface defects in the writer's experience, was the location of porosity, a type of weld imperfection which, due to the relatively small size of the individual centers of magnetic disturbance, would seem to offer the least opportunity for location by magnaflux. In this case the welds of nine, 20-inch, integral reinforcing pad, extended neck manways, each located in an elliptical head, were magnafluxed before the heads were attached to the cylindrical sections of the vessels. The inside weld between the vessel and the extended neck had been built up two heads higher than the inside surface of the head and had been chipped and ground flush. No porosity was visible on the surface. In making the magnaflux test on these welds, the powder clung to the surface in many small spots on three of the manway welds after the bulk of the powder had been blown away with a mild air jet. A number of individual locations of spots where powder clung were marked, the magnaflux test repeated and the powder adhered to the same spots. Chipping these welds opened up areas of considerable porosity coming to within $^1/_{16}$ inch of the surface.

In conclusion, while many defects have been located by magnafluxing, the defects, with the exception of the three cases mentioned above, have all been cracks which extended to the weld surface. It has been pointed out that on several occasions known defects in welds were not found by magnaflux testing. However, magnaflux testing is exceedingly well adapted to some types of weld investigation. In testing the large amount of welding contained in a magnetic stainless steel vessel liner, no other type of test with which the writer is familiar will in-

dicate the cracks as completely. However, a valuable supplement to the magnaflux test on lined vessels is a hydrostatic test using a light oil. If a liner is not bottle tight, oil will collect between the liner and the carbon steel plate. When the vessel is opened and drained the oil will seep out of any cracks in the liner for sometimes as long as a week. Although the oil test will not disclose all the cracks in the liner, it may disclose some defects overlooked in the magnaflux test.

As a final test of vessel welds, such as those around nozzles and manways, whose position makes them impossible to X-ray, as a final test of the longitudinal and girth seam subsequent to radiographing and stress-relieving, or as a final test of Class 2 vessels, magnafluxing is of definite use in determining whether these welds are cracked. Thus, the magnaflux test as applied to pressure vessel welds is a useful auxiliary to the X-ray test, and should a technique be developed which would locate sub-surface defects more readily the magnaflux test could be of even greater utility.

Careful Procedure Assures Success on Bronze-Welding Job

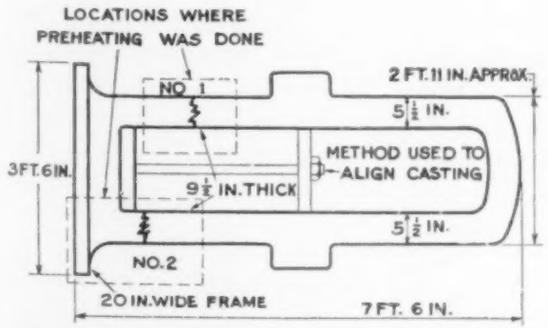
By J. C. CARTER*

THE size of the casting and the location of two serious fractures in the legs of a large press frame offered certain problems of alignment and preheating for welding. These difficulties, however, were separately and easily overcome by an interesting bronze-welding operation.

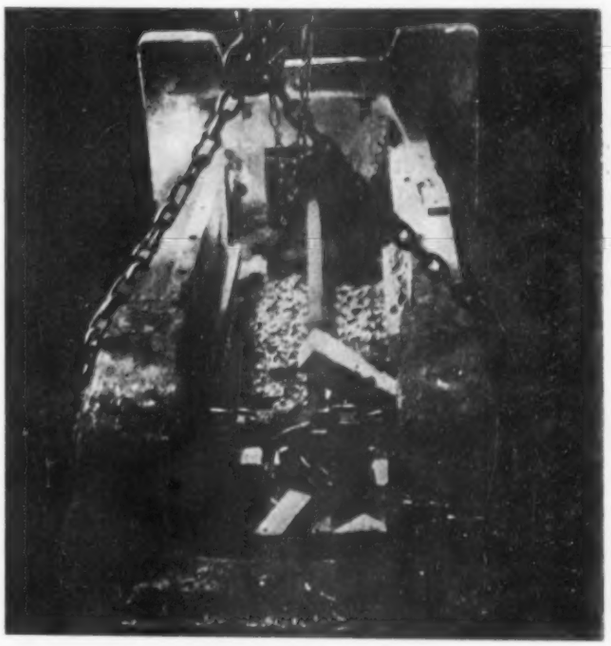
As will be seen in the sketch, this press frame was $7\frac{1}{2}$ ft. high, about 35 in. in overall width. The two legs were each about $5\frac{1}{2}$ in. wide and $9\frac{1}{2}$ in. thick. The frame snapped off across each leg.

The casting was propped up on fire bricks. Then each fracture was thoroughly veed out from each side of the leg. In order to preserve alignment, a heavy piece of bar steel was fastened across the middle of the frame, and through the center of this a long rod was passed. This rod was screwed into the bottom of the frame, and a nut was screwed on the other end over the steel bar in order to draw the base and the upper part of the frame together in a straight line.

As the diagram also shows, two small temporary preheating furnaces of fire brick were built around each fracture. Both furnaces were fired at the same time with charcoal as fuel. The location and approximate size of these temporary furnaces are shown in the sketch.



Sketch of the Press Frame Indicates the Location of the Fractures and the Preheating Furnaces as Well as the Method of Maintaining Alignment



Bronze-Welded Press Frame After Completion, with the Alignment Jig Still in Place

When the casting had reached a dull red heat, the fracture marked No. 1 in the sketch was welded first. High strength bronze welding rod was used. The vee on the top side of the other arm, marked No. 2, was welded next. The casting was then turned over and the other side of the vee filled in with bronze.

About 115 lb. of high strength bronze welding rod and approximately $4\frac{1}{2}$ lb. of Brazo flux were utilized on this job. The preheating and preparation work required about 50 small bags of charcoal, and $\frac{1}{2}$ roll of asbestos.

The actual welding time amounted to 20 hr. for four different welding operators. Standard welding blowpipes were used and fitted with next to the largest size welding heads available. When the job had been completed, the castings at each weld point were thoroughly covered with ashes and asbestos paper and permitted to cool slowly until completely cold before uncovering. On checking up after the job was completed the alignment was found to be satisfactory.

* Technical Publicity Department, The Linde Air Products Company.

List of Specifications for Steel Suitable for Fusion Welding*

(Compiled by A. S. T. M. Issued 1933; Revised 1935)

IN PREPARING this list of American Society for Testing Materials specifications for steel suitable for fusion welding, the committee is mindful of the fact that welding technique is of fundamental importance.

While the lower carbon steels are naturally easier to weld, other factors being equal, steels up to 0.35 per cent carbon have been welded with satisfactory results under the usual commercial practice. Other steels can be fusion welded satisfactorily when suitable fluxes and filler metal are used and proper working conditions are observed.

The committee considers that steel made under any of the specifications listed below can be fusion welded satisfactorily. Normally, steel made under any of these specifications will run under 0.35 per cent carbon. When special chemical limits are required they should be specified by the purchaser.

A 7 – 34.	Standard Specifications for Steel for Bridges
A 9 – 34.	Standard Specifications for Steel for Buildings
A 10 – 34.	Standard Specifications for Mild Steel Plates
A 113 – 33.	Standard Specifications for Structural Steel for Locomotives and Cars
A 131 – 33.	Standard Specifications for Structural Steel for Ships
A 30 – 33.	Standard Specifications for Boiler and Firebox Steel for Locomotives
A 70 – 33.	Standard Specifications for Boiler and Firebox Steel for Stationary Service
A 114 – 33.	Standard Specifications for Marine Boiler Steel Plates
A 149 – 35 T.	Tentative Specifications for High Tensile Strength Carbon-Steel Plates for Pressure Vessels (Plates 2 in. and Under in Thickness)
A 150 – 35 T.	Tentative Specifications for High Tensile Strength Carbon-Steel Plates for Fusion-Welded Pressure Vessels (Plates Over 2 in. up to and Including 4 in. in Thickness)
A 78 – 33.	Standard Specifications for Steel Plates of Structural Quality for Forge Welding
A 89 – 33.	Standard Specifications for Steel Plates of Flange and Firebox Qualities for Forge Welding
A 129 – 33.	Standard Specifications for Open-Hearth Iron Plates of Flange Quality
A 83 – 34	Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes
A 105 – 33.	Standard Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (Classes A and B steel only)†
A 106 – 34 T.	Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service†
A 53 – 33.	Standard Specifications for Welded and Seamless Steel Pipe†
A 134 – 32 T.	Tentative Specifications for Electric-Fusion-Welded Steel Pipe (Sizes 30 in. and over)
A 139 – 34 T.	Tentative Specifications for Electric-Fusion-Welded Steel Pipe (Sizes 8 in. to but not Including 30 in.)
A 135 – 34.	Standard Specifications for Electric-Resistance-Welded Steel Pipe
A 120 – 34 T.	Tentative Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses
A 82 – 34.	Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement

†With carbon content not over 0.35 per cent.

* Under the standardization procedure of the Society, this list has been prepared by and is under the jurisdiction of the A. S. T. M. committee A-1 on Steel.

This list comprises a revision of the List of Specifications for Steel Suitable for Fusion Welding (A. S. T. M. Designation: A 151 – 33), 1933 Book on A. S. T. M. Standards, Part I, p. 77, which list it supersedes.

FILING CLASSIFICATION OF Welding, Brazing, Soldering and Cutting Processes, Materials and Applications

▲

THIS Classification prepared by a Committee of the AMERICAN WELDING SOCIETY may be used as either a filing system or an indexing system. When used as a filing system the folders are numbered and filed in accordance with the proper classification number. When used as an indexing system the folders may be numbered and filed serially and a card index maintained in accordance with the proper classification number or numbers.

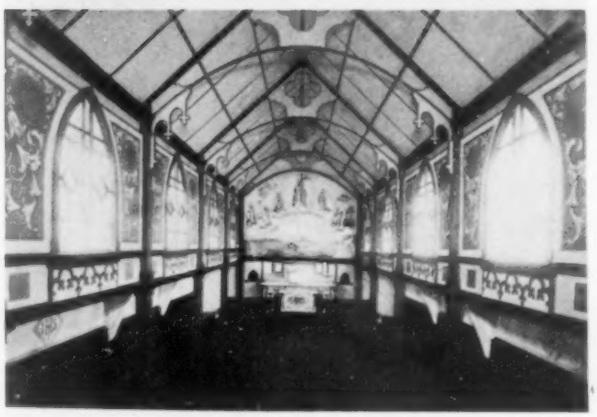
A limited number of copies have been prepared in mimeograph form and are available at 50¢ per copy.

Pictorial Review

By A. F. DAVIS*

Argentinians Now Worship In World's First Floating Church

BUENOS Aires, Argentina, December 1st—Getting to church has been a problem on the Delta of the Parana River in the Argentine. Church goers have had to ford many of the streams which thread the Delta or miss formal worship. Recently the problem was solved. The answer, supplied by a practically minded "Padre" and illustrated here, is the world's first floating church. Now the place of worship, with its steeple, stained glass windows, its Padre and altar goes to the congregation!



Inside and Outside Views of Floating Church

This floating church, 108 feet long, was built in the government's Buenos Aires shipyard. The hull is that of an old vessel. It was transformed into a place of worship by the modern arc process of welding.

New Trailer Believed Largest Ever Equipped With Pneumatic Tires

A NEW trailer, believed the largest capacity ever equipped with pneumatic tires was recently delivered by the Rogers Bros. Corporation, Albion, Pennsylvania, to a customer at Los Angeles, California.

The new trailer is of 30 ton capacity and is used in hauling steam shovels (see photo) and other extra heavy equipment. The overall length is 47 feet 9 inches, width (at deck) 11 feet 6 inches. Construction is entirely arc-welded.

Trailer of 30 Ton Capacity Believed Largest Ever Equipped with Pneumatic Tires. Construction Is Entirely Shielded Arc-Welded

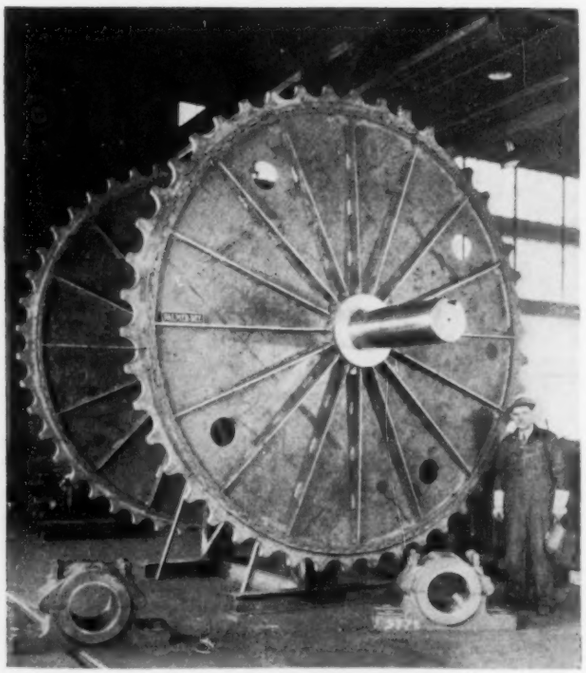
Rear View of Arc-Welded Steel 30-Ton Capacity Trailer

Sprocket Wheel

This 13-foot diameter sprocket wheel, largest of its type ever made, exemplifies progress in the use of modern manufacturing processes. Fabricated by electric welding, the sprocket met specifications requiring a finish within $^1/_8$ inch of exactness. Anything less than one inch of exactness was considered impossible by an alternate and older method of construction.

The wheel consists of a hub 15 inches thick, 17 inches outside diameter; a web $^3/_4$ inch thick, 12 feet diameter, stiffened by $^3/_4$ inch plate braces; a rim 2 inches thick by 5 inches wide; teeth made in 8 steel castings—7 castings of 6 teeth each and one casting of 4 teeth.

* Vice-President, The Lincoln Electric Company.



Welded Sprocket Wheel

These parts were fused into an integral unit by shielded arc welding. The wheel rotates on a shaft 12 inches in diameter.

The sprocket was fabricated by the Palmer Bee Company, Detroit, for a vertical core oven in a manufacturing plant.

Welded Industrial Building

By A. L. LOW*

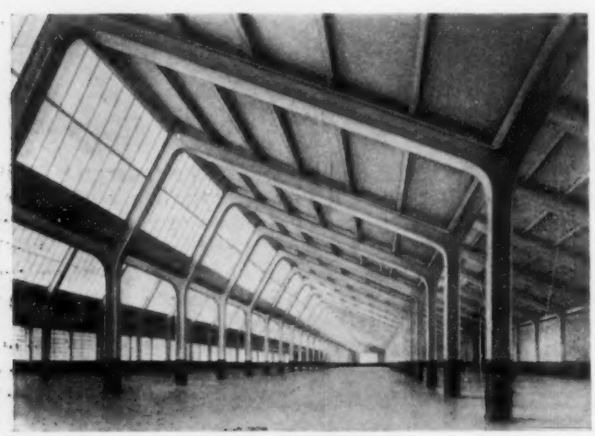
A NEW design for single story industrial buildings, providing broader factory aisles, unobstructed head room to full ceiling height, and maximum uniform daylight throughout, has been developed by The Austin Co. through the use of welded rigid frame construction

Entirely stripped of cross members and trusses which cast spider web shadows across most factory areas today, the new type has a continuous rigid saw-tooth frame formed by the welding of rolled beam sections which permit economical construction of aisles up to 50 feet in width. It is particularly adaptable to requirements of machine shops, precision parts production, and the textile, food and printing industries, where air-conditioning is a factor of increased importance.

By taking advantage of a system which utilizes the controlled elastic deformation of structural steel in a building of the saw-tooth type, it will be possible to eliminate all passing shadows caused by transitory sunlight and to insure more efficient and uniform artificial illumination at night. The advantages of saw-tooth construction have long been recognized but until now these have been confined to the glareless qualities obtained by facing monitors to the north. With all non-functional members eliminated, the new type will give unobstructed space for ventilating or air conditioning ducts, pipes and other functional equipment.

With broader aisles available, and clear unobstructed head room from floor to roof, men responsible for production will have the maximum opportunity to develop efficient and flexible operating layouts for the future. Straight line operations in any of several directions will be possible.

* Vice-President, The Austin Company.



A New Industrial Building Type

Hard Facing*

SEATING surfaces hard-faced with this non-ferrous cobalt-chromium-tungsten alloy are used for all types of gate, globe, angle, check, needle, safety

* News Release, Haynes Stellite Company.

Hard-Facing the Seating Surfaces of High-Pressure, High-Temperature Steam Valves with Haynes Stellite Prolongs Their Life from 6 to 10 Times

The Welding of Alloys Made Decided Progress During 1936. Typical of the Growing Use of This Fabrication Work Is the Job Shown Below. The Operator Is Making Fittings of Stainless Steel for a Permanent Residential Terrace Awning Fabricated Entirely of Chromium-Nickel Steel Tubing

In Heavy Construction Work, Welding and Cutting Have Proved Indispensable. Typical of This Is the Preparation of Large Diameter Caissons for Rotary Sinking, as Is Being Done on a Large Elevated Highway Project in the East. Saw Teeth Are Cut, Bent and Hard-Set for Abrasion Resistance by Means of the Oxyacetylene Flame

non-return, blow-off and regulating valves where operating conditions demand that the seat and disk material be free from galling or seizing and also be corrosion resistant.

Illustrations show the application of hard-facing.

Welding Can Take It*

RECENT drop tests conducted by The Davis Welding & Manufacturing Co. of Cincinnati with a 150-gallon welded tank fabricated from 14 gage Yoloy hot-rolled steel indicate the reliability of this nickel-copper alloy steel for truck tank construction.

The test compartment was of the type used by this large fabricator in multiple compartment vehicle tanks for hauling gasoline, oil and other petroleum products. It was welded by electric arc with coated electrodes.

150-Gal. Welded Yoloy Tank after Second Drop from a Height of 30 Ft. Filled with Water

After the tank had been filled with water, it was dropped from a height of 30 feet onto a heavy metal plate. The tank was intended to have hit on the extreme end of the oval section but actually landed on the one corner seam at the first drop. There was no indication of any break in the weld and the test was repeated from the same height. The tank landed on the opposite side on the second test, which also failed to disclose any weakness in the weld.

The substantial reductions in weight made possible by the increased strength of Yoloy have been an added factor to commend its use in gasoline tank truck construction. It is a product of The Youngstown Sheet & Tube Co.

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* From News Release The Youngstown Sheet & Tube Co., Youngstown, Ohio.

Rail End Building Up and Heat Treatment by the Arc Method*

By C. B. BRONSON†

THE application of the arc method to rail end building up is of comparatively recent origin—a matter of some fifteen years. Our own experience is confined to about the last six years, and with a single exception, has all been contract work.

Both A.C. and D.C. types of equipment were used. The resulting welds are quite comparable in their various physical and structural aspects.

The types of rods available vary over a wide range from plain high carbon to alloys in various combinations. Even stainless steel was tried on one road which has given a good account of itself after a period of five years, though it was quite costly. In the use of rods they again vary from those which are virtually bare or uncoated to heavy and complex types of coatings. In the earlier work, there was a tendency to strive rather for extreme hardness—values up to 500 Brinell being not uncommon, but with the penalty of brittleness and quite a number of shell outs or chipping. It seems more desirable to have the resulting welds tougher and lower in hardness. A figure of 400 Brinell is ample, in fact around 350 should be satisfactory, all things considered. The fact is somewhat overlooked that it is impossible to eliminate batter entirely. All we can do is to slow down the rate materially. This latter remark perhaps belongs under the heading of rail end treatment but in view of the fact that the arc method of rail end building up produces a comparable hardness increase, it is mentioned at this time.

Another point which should be borne in mind—and this applies to all classes of welding—that is, too much emphasis is sometimes placed on the unit cost of the job rather than quality. A few cents more per joint may be the difference between good results and those of indifferent value. There is no profit in having to reweld or repair rail ends at short intervals. In fact, with the added hardness in the welded area over that in the body of the rail the period for subsequent rewelding, if any, should be materially lengthened.

The arc, of course, produces an intense heat and rapid fusion of metal. The speed of application can be controlled from the electrical characteristics of the equipment, and by the size and type of rod. There is also evidently considerable difference of opinion and practice in the type of pattern to follow in laying the metal on the rail head.

It is, of course, necessary to grind the deposited metal to a true surface as well as to cross slot or end chamfer for the joint gap, which has the advantage of showing up any important defects at the point of maximum punishment under service.

The question has been raised as to whether a sufficient heat effect was transmitted to the splice or joint bars to soften them. We investigated this, and I believe others also, by removing bars, taking tensile tests at various places in the head and found no appreciable impairment in tensile strength or the other physical properties.

In the light of past experience and results, it seems that pre-heating the rail ends to some 600 to 700° F. and likewise post-heating to about the same amount are necessary and desirable. The former aids in preventing checking and consequent cracking out of zones on or near the surface. The latter slows down the cooling through the secondary brittle zone and further acts as a strain reliever. Improvements in practice or procedure should have some influence in avoiding failures if they are any good at all.

Regarding failures—that is chipping or shelling out, etc.—there is no use in making the statement that they have not occurred, for it would be contrary to general experience. The percentage or number varies depending on many factors, one of which of course is the type of service, and another important one in the human factor which is quite a controlling influence. Some failures developed where arc welds were applied over old gas welds which were not burned out to sufficient depth to permit proper bond or fusion. Another cause is the practice of going back and hastily applying small deposits of metal on cold steel, because of some minor casting defect which shows up when the grinding is done. These small deposits are generally extremely hard which develop into cracked out areas, and therefore does more harm than good. Many failures were attributable to this practice.

We should bear in mind that rail end welding of any type is a casting proposition primarily and applied to rolled material. However, most of the casting defects are largely avoided with proper rods and practice and make a pretty smooth resultant surface with few blowholes or cavities. Where they do show up it is better to leave them alone than make a hasty patch on the cold rail.

Another source of some failures was due to the much higher degree of hardness where the run off from the weld joins the parent or normal rail head metal. Scleroscope checks have been made of a large number of rail ends and show as much as 15 to 25 points higher in this zone compared to the hardness directly at the rail end. Here again is a reason why a rather thorough pre-heating may be advantageous to aid in creating more nearly uniform hardness throughout the welded area.

Before leaving this subject a word or two might be said as to what criteria should be used in determining whether a given stretch of track needs rail end welding. Along this line, I believe that the basic cause for a good share of the so-called bad riding joints is not true batter but from the effect of loose fitting and worn bars. Frequently the difficulty can be corrected by changing bars, reversing them or shimming. In any event it seems to me to be desirable to fix up the joints first before any welding is done, that is on major operations, for the best results. If this is done afterward, the entire

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* Presented at joint meeting of Chicago Section, AMERICAN WELDING SOCIETY and Maintenance of Way Club of Chicago, December 14th.

† Inspecting Engineer, New York Central.

relation or position of the abutting rail ends may be materially altered.

It is again repeated that in our experience much of the alleged batter is not that, but joint bar trouble, and by correcting the out of level condition, plus a small amount of surface grinding we can smooth off the joint in a satisfactory manner without welding.

It is noted that some roads of relatively moderate traffic density resorted to rail end building up after about three or four years of service. There must be something basically wrong to require this after such a short period. It seems to me that rail properly set-up, in the first place, and maintained should under average traffic conditions give at least eight to ten years if not longer before any building up would be necessary.

As to rate of batter, our experience indicates that there is no straight line ratio or type of curve showing concordance against any given unit of traffic density. There are sufficient variations in the track structure from point to point to make a material difference in batter rate. In a given stretch of track this actually varies over a considerable range. There are many of these joints which could easily be passed up because of the slight extent of the batter, and under such conditions it seems more reasonable and justified to spot weld only.

These points are not mentioned with the intent to discourage rail end building up, in fact it would have probably little if any effect on the decision of any one individual. The point is that adequate consideration is necessary of all the phases of the proposition, as well as the elements in the track structure, particularly the joint bar assembly.

With reference to the second subject assigned, that is rail end hardening by arc or electric methods, to the best of my knowledge there is only one company doing work of this nature. I do not know of any railroad that has gone into this type of work independently either.

The first installations or trials were done in the field, using three separate machines, one to preheat, the second unit to flash or oscillate the arc across and lengthwise of the rail, and an oil spraying device for the quenching operation. Various devices were incorporated from time to time to insure uniformity by close control and timing the sequence of the three steps in the process.

The apparatus was subsequently modified slightly and used at two or three rail mills for end hardening of new rails.

Information from a reliable source develops that an induction method is about ready to go into commercial use, and will be applicable in both the mills and the field. Induction heating should be more uniform and better distributed, than that from the arc, and with less likelihood of burning the surface or cause scaling.

Our experience with rail end hardening with the arc, in fact any form or method, is very limited, and this was only in the field. Three years ago we had 1500 joints so hardened and outside of this we have done very little, though we have kept closely in touch with work from various sources. The 1500 joints mentioned were in groups of 500—mostly on tangent track and in fast service. This was also one of the earlier experimental jobs, and although there are many checks or cracks at various places in the running surface, only two or three actual shell outs have occurred in about three years of service.

Objection was voiced by some to the way surface seams were opened up on the running surface. Most of these have since been rolled out, and have not proved troublesome or injurious.

Representative stretches of these and similar rails with unhardened ends have been periodically checked for batter, but the difference so far is slight, representing about $^1/_{128}$ inch in favor of the treated ends which have a Brinell hardness of about 400. The length of batter is somewhat longer for the unhardened ends. We have not observed any tendency for the metal to abrade—or what some call batter—just beyond the hardened zone.

In closing, a few general remarks are made about field mill end hardening or rail ends. Doing the work at the steel mill has some obvious advantages among which are probably more accurate control, the possibility of varying the treatment in accordance with the carbon content or chemistry of each heat of rails, and perhaps the most important is that the treatment is done before any traffic has passed over the rails. Work in the field is sometimes delayed and in the meantime a certain amount of initial batter or flow occurs.

One other remark I would like to make is this. Rail steel like any of the other forging or hard grade steels needs to be treated with extreme care. Temperature and quenching conditions must be closely controlled. End hardening of necessity has to be done under conditions far from ideal, that is in many cases in the open in all kinds of weather—a remark which pertains to both the mill and the field—and to be economically accomplished is done in a relatively short time, generally a few minutes. Contrast this, let us say, with heat treatment of automative or locomotive parts where the closest control of conditions is considered and recognized from experience as necessary.

For this reason I somewhat question whether end hardening is going to be a gain or a loss in the long run of service—a fact which I know many of you will readily dispute. We realize of course that there is a strong, concerted popular demand by the railroad for the same, and it is hoped that success will be the result.

Again I do not wish to appear as questioning the judgment or decision of any one, nor of discounting in the least the good work and development fostered by the rail mills, railroad supply companies specializing in this sort of work, nor the railroads themselves. Batter conditions so far as we are concerned are not as serious as some probably believe. And in view of this for the time being we have deferred rail end treatment, except to the extent of fair sized demonstration; this decision also taking into account that an extensive investigation is now in progress through the Rails Investigation at the University of Illinois, fostered and financed by both the rail mills and the railroad association, which will bring out many pertinent facts covering the entire problem. This investigation should carry great weight in evaluating the success or otherwise of various types of treatment, and indicate, from the tests, the direct influence on the preservation of rail ends.

We are also readily aware that any and all methods should receive impartial treatment in view of the great necessity of prolonging the life of rail in its larger aspect.

Fusion Welding as Applied to Frogs and Crossings*

By S. E. TRACY†

YEARS ago, with the advent of heavier motive power, it became evident to operating officials that one of the most important improvements in upkeep of track structures was the maintenance of frogs and crossings. As a matter of safety and economy there was a demand for research in this field. The welding processes were in their infancy, and metallurgical advances were limited. The service and supply organizations, who fulfilled the requirements of railroads, took the initiative in this development with the cooperation of the railroads. The development through a process of evolution has produced thoroughly dependable welded structures capable not only of supporting heavier equipment, but in addition it is equally well withstanding the service required by the present day ultra-high speed equipment. It was not so easy to convince a roadmaster that he should have a welder to take care of frogs and crossings on his territory. Today, it is impossible to convince the same roadmaster that he should not have a welder to handle this work in his territory.

If we look back at the results, even the appearance of some of the early welding that was performed, on either open-hearth or manganese, it is not surprising that that roadmaster had taken his stand, and at the same time it is not surprising that he has been converted when we stop to consider the transformations that have been made in welding apparatus and welding rod, in welding practices and standards, and in the technique in the application of metals.

There are now many important welding and cutting operations that are being performed successfully on every railroad. The practices, the methods, the equipment and the materials that are used vary on the different railroads. We have conditions that are peculiar to our railroad, and, perhaps, you, as individuals, have conditions that are peculiar to other locations on your railroad; so our methods and practices, of which you are about to hear, may or may not be applicable to your particular condition, but we have had sufficiently satisfactory results with our practices over an adequate period of time to justify certain definite conclusions.

Our standard practices include the exclusive use of the oxyacetylene process in the welding of open-hearth frogs and crossings or other similar materials; the exclusive use of the electric process in the welding of manganese frogs and crossing sections. It may be stated here that we weld most of these parts in track under traffic rather than to send them to a centralized shop.

We use the oxyacetylene process in the welding of open-hearth frogs and crossings not because it is impossible to make a weld on this material with the electric process, but because we have found, through experience and from observation on our neighboring railroads, that the former is less harmful in its effect upon the parent metal; there is less chipping, cracking or breaking of the welded parts; the equipment is easier to get around through yards and between locations; the investment is considerably less; and in the end it is more economical.

At the present time we have ten of these open-hearth frog and crossing welding units, consisting of one welder and one laborer. The units, most of which are equipped with bunk cars and tool cars, are stationed in the largest yard in their respective territories; although in certain districts, where there are many small yards, the units move about so frequently that they have no regular headquarters.

In either case the units are transferred from one location to another, under the direction of the district engineer maintenance of way, as often as may be necessary to keep all of the frogs and crossings in good running condition.

When the welder is moved to any location, unless he has been sent there as an emergency move to correct some special condition, it is the intention that he build up all of the frogs in that yard that are in need of welding.

That brings up an apparently simple question—How does the welder know or determine that a certain frog is in need of welding? The answer to that question would be comparatively simple if getting the welder to any frog on his territory, or any such frog to the welder, could be accomplished upon a "Magic Carpet." You, of the welding industry, would not recommend that a certain size electrode or welding rod, or that a certain kind of rod be used unless you knew something about the conditions and the material upon which they were to be used. You as a manufacturer of welding apparatus and materials would not recommend a certain piece of equipment to one of your customers unless you knew something about the purpose for which, and, perhaps, the conditions under which it was to be used. You, a maintenance officer, would not recommend a change in roadway or the replacement of a stretch of rail unless you knew something about the existing conditions at the particular point in question.

So it is with our frog welding. Before the welder can make an intelligent decision upon the advisability of welding a certain frog, he must have the answers to these pertinent questions: Has the frog been welded before? How long has it been in service in its present location? What is the general condition of the running rails, the bolts and the filler blocks? What kind of traffic passes over the frog and at what speed? How many frogs are there in this vicinity that are in a comparable condition? What is the accessibility of the location?

The answers to these questions, of course, will vary with the location, but collectively they are the gage by which we measure. We have a standard practice book which the welder is required to follow in principle. We think that this practice results in better maintenance of our frogs in general, and, therefore, we do not specify a

* Presented at joint meeting of Chicago Section, AMERICAN WELDING Society and Maintenance of Way Club of Chicago, December 14th.

† Track Welding Supervisor, Chicago, Burlington & Quincy.

definite minimum wear to suit any and every condition. If it were expedient to do so, we would establish the minimum wear at approximately five-sixteenths of an inch. That figure would represent the distance between a straight-edge and the inside edge of the wing rail with the straight-edge being placed across the frog, one wing rail to the other, in the vicinity of the thin end of the frog point.

We have been convinced that it is better to reclaim a frog in its early stage of wear than it is to allow the frog to remain in track until it reaches its maximum wear. There is less trouble with warpage from welding or surface bending under traffic; the bolts are easier to keep tightened; the bolt holes in the frog point will not become enlarged, nor will the bolts become bent as quickly; and, the filler blocks will serve their purpose better in holding the point rails and the wing rails in their true relative positions as to height and flangeway clearance.

When the bolts become bent and the filler blocks become worn to such condition that the frog point has sagged and worn, over three-sixteenths of an inch below the wing rails, at the first point of wheel transfer from the frog point to the wing rails, the cost of welding the frog is increased, and the good riding qualities of the frog are decreased in proportion to the amount of sag.

At one time it was our welding practice to apply enough metal on every frog point to bring it up to its original height—level with the wing rail, at this point of wheel transfer; regardless of the depth of the sag plus the usual wear. Our present practice is to apply only such metal as may be necessary to raise the top surface of the frog point so that it will be not more than three-sixteenths of an inch below the top surface of the wing rails at the first point of wheel transfer.

There is so much variation in the car wheels that pass over any frog that it is quite impossible to set-up a condition that will provide a smooth transfer for all of them at the same place. This fact had much to do with our change in practice, and we have had better results since the change was made.

It is our thought that the details of our welding procedure on open-hearth frogs and crossings would not be of general interest upon this occasion; so we will proceed with our experiences and conclusions on the welding of manganese frogs and crossings. All of our manganese frogs and crossings are welded by the electric process. Our attempts to use the oxyacetylene process on this material have resulted in complete failure, and in destruction to the castings. We have been welding manganese frogs and crossings, both the solid and rail-bound type, for about 11 years.

During the early part of the period the results were very discouraging, but intermingled with the numerous failures there were enough encouraging results to indicate possible success. We tried every conceivable way of performing the work in the hope that the results might be improved. We tried the carbon arc, the oxyacetylene cutting torch, and the grinder, or a combination of the three, for removing loose and laminated metal. A grinder and a sand blast or both were used to clean the surface of the parent metal before welding. We tried pouring water upon the deposited metal before peening it and after peening it. We kept water in the flangeways, used air hammers and different weights of hand hammers to peen the metal, deposited the metal in short, long, wide and narrow beads or beads crosswise and longitudinally, and, we tried preheating to various degrees of temperature. About the only thing that we did not try was the welding of a manganese section that was not ready for the scrap pile. Our results then would not justify welding on frogs that are today routine jobs.

If, in the end, we were successful in getting a likely-looking frog by any of the combinations of methods, we placed a serial number upon it, and kept a book record of the methods that were used in performing the work. The frog was placed in track at a picked location. Inspections were made from time to time, or the frogs were returned to us as failures. From our records we were enabled in determining the combinations of methods that were proving to be the most satisfactory.

Finally, from all of the data that had been accumulated, we found that the frogs upon which the most simple of the combinations of methods were used had given as satisfactory results as any of the frogs upon which any of the other combinations of methods were used; therefore, the following methods of procedure were selected: Remove the loose or laminated metal by the use of the oxyacetylene cutting torch and, or a grinder; deposit the metal in thin, narrow beads longitudinally with the worn sections; peen the deposited metal with a hand hammer after each one-half electrode; deposit the metal upon the worn surfaces intermittently where practicable to do so and, in finishing round off the sharp edges of the wing and point sections. Most of this experimental work was done in one of our shops.

In 1929 we purchased a portable electric welding unit in order that the work might be done in track. Most of the frogs that were welded in track were not as badly worn as those which we had welded in our shop, and we found that the results were better although we used the same methods in doing the work. We had some failures and we have failures today, but there is this difference. The former failures occurred after a comparatively short period of time. Today, if they occur at all, they occur after several months of service. We think that the use of nickel content manganese welding rod is responsible for this difference. Many of the failures that we have had in the past have occurred in the parent metal slightly below the line of fusion.

We find that many of the solid manganese frogs and crossings develop cracks somewhere in the section, generally after they have been in service for some time. In many cases the cracks are not of a progressive nature, but in certain locations on the castings they do progress to such point that repairs are necessary.

We have attempted to repair these cracked sections by V-ing the sections adjacent to the crack and welding but the results were not satisfactory. During the past several months we have been making repairs to these cracked sections by laying some nickel manganese bars of various thicknesses across the crack and welding them to the outer surface of the section. This method of repair has given satisfactory results up to date. In accordance with our third conclusion, most of this manganese work is now done in track, but we have one shop to which any emergency job may be sent if our portable track welding unit is not immediately available.

We have two locations on the railroad where open-hearth frogs and crossings are repaired. The materials removed from track at outlying points, and those removed in connection with track changes, replacements or relays are sent to these locations for repair. The materials that are repaired are placed in store, stock for shipment to any location for which requisition is made. We think that this is an important thing to be considered in connection with the welding of frogs in track or at a centralized location.

Many of the frogs that are repaired in track or on the ground in the immediate vicinity thereof are made suitable for several years of satisfactory service because

the conditions under which the frog is to be used are known. A frog that is sent to a centralized shop for repairs must be in such condition that after it has been welded it will be suitable for any location because the conditions under which the frog is to be used are not known.

The welder in a centralized shop generally does not have occasion to inspect the frogs that he has welded after they have been placed in service. If he does inspect them he has no idea of how long the frog has been in track, or when the work was done. The welder in a yard or in an assigned territory does have an opportunity to inspect his work quite frequently. Our welded frogs are marked with the welders identification number and with the date if welded in track. From the inspections the welder is enabled to see and to correct some condition in his method that the former welder would know nothing about.

We found these conditions to be particularly true in the welding of our manganese frogs and crossings. By doing the work in track the operator can and does watch the effect of traffic upon the completed frog and correct the errors that he has made in finishing.

We realize, too, that there are certain advantages in the welding of frogs in a centralized shop. The facilities for handling the frogs are better; there is less delay to the welder because of traffic or weather conditions; and, it is more practicable to use an acetylene generator. These things result in a reduction in welding costs, perhaps, but when we took into consideration the investment in additional emergency or replacement frogs, the cost of removing, replacing, shipping and inspecting the frogs removed from track, the cost of welding the rail ends or replacing the rail in track so as to match the rail on the replacement frog, and, as previously stated, the frogs can be welded suitable to the location, it was our thought that greater savings in maintenance could be effected by following the methods which we have outlined.

The perpetuation and extended use of these practices are inevitable.

Construction of Welded Pressure Vessels for the Petroleum Industry*

By R. K. HOPKINS†

Introduction

THE chemical and petroleum industries probably have more welded pressure vessels in service than all others combined. This is due to the peculiar need in these industries for absolutely leak-proof vessels for extreme high temperature and high pressure service.

Thousands of tons of riveted vessels have been used, and a great many such vessels are still in use, but due to their inherent propensity for developing leaky seams, only a very few are being purchased as new equipment in America today, and it can be safely said that no more are being put into service where the operating conditions are at all severe.

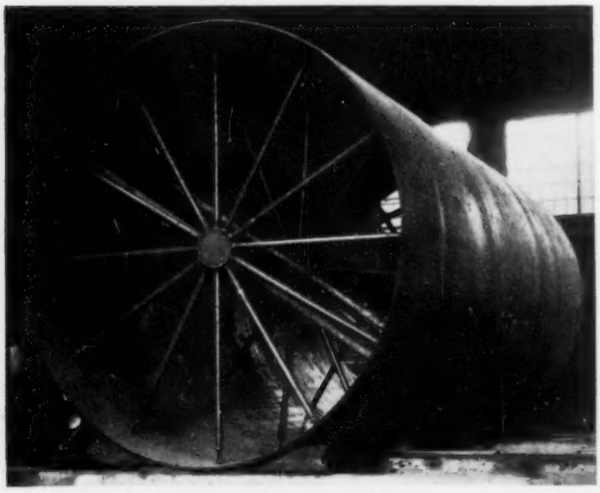

Fig. 1—Bracing Required in a 16-Ft Diameter Tower

Some years ago the riveted type of vessel was to a great extent superseded by the forge and hammer-welded type. This latter had a great many points in its favor, chief of which was its almost leak-proof joint. But the extent to which this method of construction could be used was rather limited owing to the inability of the manufacturers to produce satisfactory seams on plates of heavy gages. Where the operating conditions were too severe for either the riveted or forge and hammer-welded types of construction, the seamless forged vessel was invariably resorted to.

All three methods of construction mentioned have filled, and one or more is still filling a very definite need, but all are being rapidly replaced by the present day fusion-welded vessel. This change has been going on for approximately the last 10 years, very gradually at first, but with the passing of each year, more and more tonnage of the latter type of vessel has been installed.

There are, of course, several variations of the fusion-welding process, such as metallic arc, carbon arc, oxy-acetylene, atomic hydrogen, resistance and flash welding. The metallic arc welding process is one of the most generally used methods. Either bare or covered electrodes may be used in this process, but since the covered electrode produces welds of so much better quality, it is quite generally used for the construction of pressure vessels where the conditions are at all severe.

Almost every demand of either the chemical or petroleum industry for pressure vessels can be met today by

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† Director of Metallurgical and Research Development, The M. W. Kellogg Company.

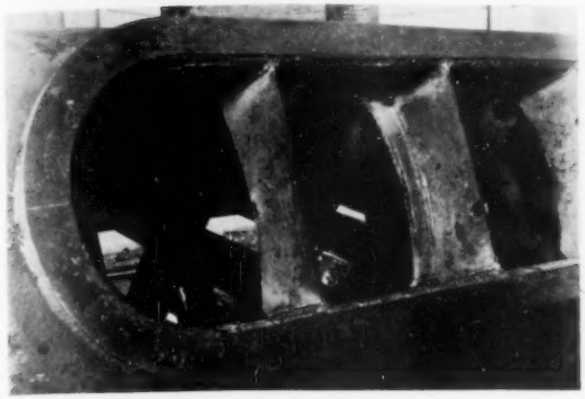


Fig. 2—Bracing an Oblong Nozzle

the use of the covered electrode arc welding process, since steel of practically any thickness or composition can be satisfactorily welded.

Although the foregoing generalities apply to the chemical and petroleum industries, space will not permit a detailed description of the pressure vessel requirements of each in this paper. What follows deals with the requirements of the petroleum industry and with vessels produced by the covered electrode arc welding process.

Pressure Vessel Requirements of the Petroleum Industry

Pressure vessels in the petroleum industry are required to meet a great variety of conditions of temperature and pressure and of resistance to chemical attack. Not only do the processes used by different refiners differ, but the crude oils processed vary widely in corrosive action.

The operations in a petroleum refinery are carried on at temperatures varying from 1200° F. down to −75° F. The pressures may vary from 1500 lb. per square inch down to a 29-in. vacuum. The corrosive properties of the oil processed may be mild enough to permit the use of regular carbon steel, or so severe as to require some form of stainless steel.

Fabrication

Where the operating temperature is neither too high nor too low, nor the corrosive conditions too severe to require a special alloy steel, the usual pressure vessels are fabricated of plain carbon steel. This steel is normally of firebox quality and has a minimum tensile strength of 55,000 lb. per square inch. But where pressures are very high, or where the finished weight of a vessel is limited by the capacity of handling equipment, either in the shop or in the field, a silicon-killed steel of 70,000 lb. per square inch minimum tensile strength is used.

Since so many articles have been written concerning the detailed construction of the usual arc-welded pressure vessel only a few general remarks will be made here to cover this phase of the subject.

As a rule, the welding groove—whether it be a single V, a double V or a U shape, is planed on all four edges of each plate before bending. Plates are bent cold, provided they are stress-relieved after bending and welding. The capacity of the bending equipment is usually the determining factor in deciding at what thickness plates are to be bent hot.

After girth welding two or more heavy walled shells together, the seam is locally stress-relieved by heating a band containing the weld in its center, in a circular furnace to approximately 1200° F. In order to prevent sagging, the cylinder is rotated during this heat-treatment.

Internal parts, such as tray angles, baffle plates and other special fittings, are welded into the shell before the heads are applied. The nozzles, manways, supports, lifting lugs, clips, etc., are usually welded in place after the vessel is otherwise complete.

At this point the vessel is thoroughly inspected and then taken to the X-ray Department where all longitudinal and girth welds are completely X-rayed. If any defects are disclosed, they are repaired and subsequently re-X-rayed.

After the welds have satisfactorily passed the X-ray examination, the entire vessel is placed in the furnace where it is stress-relieved at from 1100 to 1200° F. Heat is applied slowly until the above temperature is reached. The vessel is held at temperature for a period of one hour per inch of thickness, and then allowed to cool with the furnace.

The temperature in a modern stress-relieving furnace is automatically controlled, but in order to reduce the possibility of faulty furnace design affecting the temperature of the vessel itself, the thermocouples are peened into various parts of the vessel rather than placed throughout the furnace.

After stress-relieving, the usual hydrostatic test is applied and the vessel is then ready for shipment.

One of the principal difficulties in the manufacture of pressure vessels is the prevention of undue distortion, particularly in excessively large vessels and those of unusually complicated design. Figures 1 and 2 show, respectively, the massive bracing required in a 16-ft. diameter tower, and a rather small condenser shell containing an oblong nozzle for practically its full length.

For the physical properties which may be expected from welded joints when properly made, the reader is referred to Fig. 3. The data used in plotting these curves were collected from five of the leading pressure vessel fabricators in America, and represent the maximum, minimum and average values of the physical properties obtained by them in welded joints on regular production work.

The values shown on these curves represent the average of those values presented by each company as obtained on the standard 0.505 in. all-weld-metal tensile bar. It will be noted that the average of the minimum values

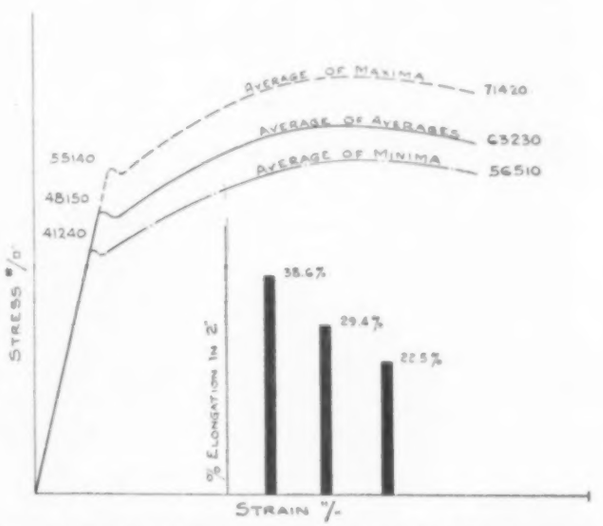


Fig. 3—Average Physical Properties of Carbon Steel Weld Metal as Determined by Thousands of 0.505-In. Tensile Bars Produced and Tested by Five, Class 1 Welded Fabricators in the United States

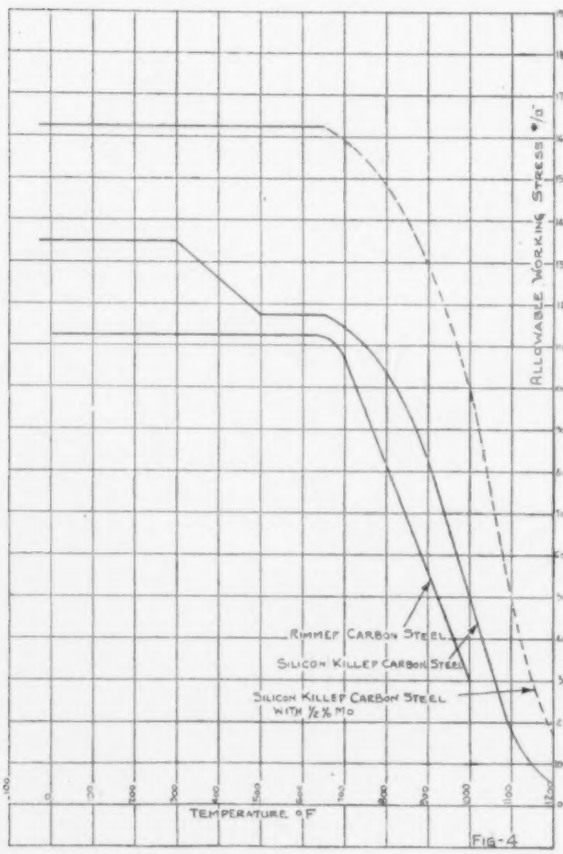
obtained for tensile strength are slightly above the minimum requirement of the Code,* namely 55,000 lb. per square inch, whereas the average of the average values obtained by the various companies is well above the minimum requirement of the Code. This same statement can be made regarding the elongation in 2 in., for which the Code requires a minimum of 20%.

The A. S. M. E. Power Boiler Code does not include a requirement for yield point of weld metal, but it will be noted from these curves that the ratio of yield point to tensile strength is well above that which is usually found in rolled or forged materials. But, as stated before, this is a characteristic of weld metal as produced today, and is extraordinary when it is remembered that these unusually high yield points are accompanied by excellent ductility as shown by the elongation figures on this curve.

Vessels for High and Low Temperature Service

High Temperatures

As stated above, in vessels for ordinary operating temperatures, that is, up to 650-700° F. the working stresses used in design are in accordance with those prescribed by the A. P. I.-A. S. M. E. Code for Unfired Pressure Vessels for Petroleum Liquids and Gases. This same Code is used for temperatures above 650-700° F. where plain steel of 55,000 lb. ultimate tensile strength is used. But in many cases, particularly where the operating temperature is very high, it has been found more economical to use a silicon-killed carbon steel where possible and beyond this point, to resort to a silicon-killed molybdenum steel. The great advantage offered by molybdenum steel at extremely high temperatures is shown by Fig. 4, which gives the recommended working stresses at various temperatures for rimmed carbon steel (55,000 lb. per sq. in. ultimate tensile strength); silicon killed carbon steel (70,000 lb. per sq. in. ultimate tensile strength), and silicon-killed carbon steel with ½% molybdenum.


ALLOWABLE WORKING STRESS #/□"
TEMPERATURE °F
RIMMED CARBON STEEL
SILICON KILLED CARBON STEEL
SILICON KILLED CARBON STEEL WITH ½% MO
Fig. 4

It has been found that the welding properties of ½% molybdenum steel are practically as good as those of plain carbon steel. This fact is, of course, of great advantage to the pressure vessel fabricator in helping to keep the overall cost of this type of vessel down. Practically the only increased cost of a ½% molybdenum pressure vessel is that due to the additional cost of the plate materials and the welding rod. A considerable tonnage of vessels of this type of material has been furnished to the oil refinery industry in America, and as far as the writer knows, no trouble has ever been reported.

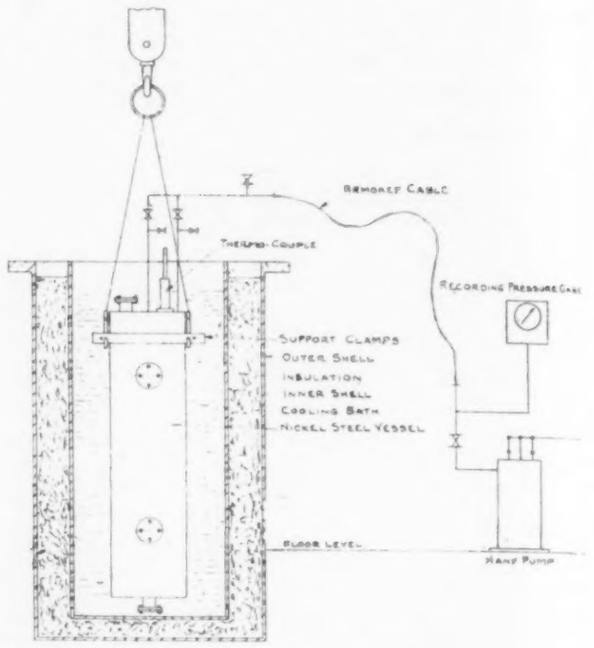


Fig. 5.—Set-up for Sub-Zero Test on Nickel Steel Tanks

Low Temperatures

It is only within the last few years that the pressure vessel fabricator has been called upon to furnish large sized pressure vessels for low temperature service. In the past, most low temperature operations were carried on in small equipment such as filter presses, centrifuges, etc. But with the advent of the propane dewaxing process and others of similar nature, large sized vessels are required to operate at temperatures usually in the neighborhood of −40° F., but in some instances down as low as −60° F. This new type of operation presented a very serious problem to the pressure vessel manufacturer since the properties of plates of steels and alloys at these low temperatures were not known. Most of the existing data were collected from tests on small samples of steel, such as angles or small rounds, and in some cases from railroad rails. Experience has shown that in investigating the properties of materials going into pressure vessels, such as large and heavy plates, test data from another type of article, even though it may be made of the same analysis steel, cannot always be applied.

When this problem was first presented to the Research

* A. P. I.-A. S. M. E. Code—Unfired Vessels for Petroleum Liquids and Gases, 1934, p. 55; W-520 Tension Tests.

Department of The M. W. Kellogg Company in 1932, an extended series of tests was run on several alloy steel plates as well as on ordinary carbon steel plates. All plates were taken from full sized open hearth heats and were in no case less than 1 in. in thickness. As a result of these investigations, a steel containing 2¼% nickel, with 0.15 to 0.25% silicon was adopted as standard, since this steel showed the most consistent toughness at sub-zero temperatures for the commercially available analyses tested. In order to check the results obtained in the laboratory, a full sized pressure vessel was built of this steel and subsequently cut up and tested. In addition, several full sized pressure vessels were built for a pilot plant and hammer tested under full pressure at −50° F. Figure 5 shows the set-up used for this test.

Two and one-quarter per cent nickel steel is a commercial steel which has been used for some years in locomotive boilers. For that reason, no special requirements were placed on the steel mill to supply this analysis. Since its adoption, several hundreds of tons of pressure vessels made of 2¼% nickel steel have been fabricated and put into use at sub-zero temperatures. The only drawback to the use of this steel is its relatively high cost, and for this reason experimental work has been going on continuously since 1932 to discover or develop a satisfactory steel for low temperature service, whose cost was not so high.

As a result of these tests, which have just been completed by our Research Laboratory, it is quite probable that plain carbon steel which has been handled by a specially prescribed method of deoxidation in the steel mill will be satisfactory. Complete details of these tests will be available at a later date.

Vessels for Corrosive Service

The primary cause of the corrosion which takes place in pressure vessels in oil refinery service is the sulphur compounds contained in the crude oils. The concentration and the kind of sulphur compounds vary widely in different crude oils, and with the locality from which the crude oil is produced; a corresponding variation exists in the corrosive action of the crude oils on the equipment in which they are processed.

Most refineries have been collecting data for years on their corrosion problems so that they are now in a position to predict the rate at which corrosion takes place when processing certain crude oils in all parts of their equipment. With these data they are enabled to determine how much additional thickness of carbon steel should be added to the design thickness of any pressure vessel or in any particular part of a given pressure vessel to insure a useful life of any predetermined number of years.

Where comparatively low sulphur crudes are being processed, it is customary to take care of corrosion, where any exists, by the addition of extra wall thickness, this method being the most economical.

Where the rate of corrosion is high, however, a number of expedients have been resorted to, to retard the rate, and in some cases to reduce it to zero. One method which has been used for years is to line the towers with some form of refractory material such as ganister or cement. This material is blown or plastered on to the inner surface of the tower, bonding it with some form of wire which is attached to the tower itself to support the lining. This type of lining has proved quite satisfactory for certain kinds of service, but the maintenance cost is, however, considerable, and in addition, it must be completely replaced at relatively short intervals, in some cases every year.

A great deal of experimental work has been carried on by refiners, as well as pressure vessel fabricators, to develop a satisfactory metal spray process. Metals of various compositions have been tested; aluminum seems to be the one most generally used. Extreme care must be taken in the preparation of the surface to be sprayed. At best, this type of lining has not proved itself entirely satisfactory, although in some cases it has shown fairly good results.

It is understood that the metalspray equipment manufacturers have made considerable advancement in the past year or so and they claim that these linings are much more serviceable than they have been heretofore.

It has, of course, been known for many years that chromium is the most resistant of all the metals to hydrogen sulfide corrosion, and many methods have been tried to apply this metal to the inside of pressure vessels. A great deal of money has been spent in the development of electro-plating processes for depositing pure chomium on the inner wall of pressure vessels, but to date no evidence is available to show that any one of the processes has been successful.

One type of material which shows a great deal of promise for this service is the bi-metal plate, which on one side has a corrosion resistant material such as a straight chrome or chrome-nickel steel, and on the other the regular carbon steel base metal.

A certain amount of trouble has been experienced in the use of this material by the occurrence of blisters, which are caused by lack of fusion in localized areas between the alloy sheet and the carbon steel base.

A new process has recently been put on the market which is quite similar to the one first described, the difference being that special precautions are taken to prevent oxidation taking place between the carbon steel and the alloy plate. Another feature of this process is that a thin skin of electrolytic iron is deposited on the surface of the alloy plate before applying it to the steel slab, this step being added—it is stated, to increase the weldability of the two materials. Because this product is relatively new, no service data are available at this time.

Another method used to retard the rate of corrosion in pressure vessels is to line the inside with a separate sheet of corrosion-resistant material. Most of this work has been done with 18% chrome 8% nickel, and with straight 12 to 14% chrome steel. These sheets, which are usually approximately 5/64 in. thick, are applied by one of two processes. In one process the sheets are perforated and subsequently plug welded with an alloy rod to the base metal. In the other process, resistance welding is used to spot weld the sheet to the base metal. In either process the sheet may be welded to the base metal either before or after bending. Special precautions must be taken to see that cracks do not develop either in the welds or in the sheets adjacent to the welds. Air testing and magnetic testing are usually used to determine whether or not such defects exist.

In the writer's opinion, the above methods of retarding corrosion have been listed in the inverse order of their value.

Although some of these methods have been quite satisfactory, they are expensive in terms of service life; that is to say—although the latter methods listed are a great deal more effective in retarding corrosion than the first methods listed, their cost is a great deal higher. Therefore, it is a question of whether it is more economical to use the cheaper and less efficient methods or to resort to the more expensive ones.

There is still a need which will undoubtedly be filled within the next few years for a carbon steel plate, corrosion resistant on one side, which can be produced for a price low enough to make it commercially practicable.

Welding of 70,000 lb. Minimum Tensile Steel

By FRED J. ESSLINGER*

THE 70,000 lb. minimum tensile steel, more specifically known as the A. S. T. M.-A-149 grade, is of a relatively recent origin. It was put on the market in 1931 and is therefore scarcely five years old. In spite of this fact, it has assumed a very important rôle among materials, and the tonnage of it that is worked and welded every year is far from being insignificant.

The first project in which 70,000 lb. minimum tensile steel was used in large quantities, was the construction of the Boulder Dam penstocks. Approximately 10,000 tons of it went into the making of the latter and, from reports available, its behavior in the course of bending, rolling, riveting and welding did not vary radically from that of lower tensile steel.

The second project, for which 70,000 lbs. minimum tensile steel was selected, was the building of a 6 ft. by 36 ft. accumulator for an eastern continuous strip mill. This vessel was expected to withstand working pressures up to 1300 lb. and, therefore, had to be made of 3-in. thick plates and heads. In this case also the material worked and welded in a way not differing greatly from that of mild carbon steel of similar thickness. The only change in procedure consisted in the use of high tensile, in place of the conventional, electrodes. The welds obtained with them proved stronger than the parent metal, fairly ductile and very sound. From a total of 100 linear feet of welding not more than 1.5 had to be cut and rewelded.

Since the completion of these two projects, the amounts of 70,000 lb. minimum steel, used in the construction of welded penstocks, autoclaves, reaction chambers and others, has grown considerably and promises to grow even more if some of the difficulties, which various of its users have experienced lately, can be eliminated successfully and promptly.

The difficulties encountered seem to be of a twofold nature and appear to center around a lack of tensile strength in weld and steel in some cases, and a lack of soundness and ductility in others. From a study of the various complaints and the materials involved, it would seem as if they all had one common cause, and that it was none other than their carbon content.

The difficulties of the first type are most likely to occur in material where the carbon content does not exceed 0.28% and the other elements are present in no more than normal amounts. Such material, when tested in the received condition, will yield tensile values ranging from 72,000 to 74,000 lb. per square inch and will therefore be quite in accord with the letter of the specifications. It may be cold-rolled, bent, hammered and it still will retain essentially the same physical properties it had in the received condition; if, however, it gets heated, welded and strain relieved and is then tested, it will often yield tensile values from 2000 to 4000 lb. per square inch lower than it did when received from the mill. The drop is never very pronounced, but since it takes place in material where the tensile strength lies closely to the border line of the specifications, it often leads to rejections. The cause of this drop can readily be traced to the combination of welding, hot working and strain-relieving, either one of which will rob the material of that part of its strength it has acquired in the course of mill rolling and makes it dependent exclusively upon the part of strength it owes to its chemical or elementary composition. The latter in a material such as here discussed is insufficient and, therefore, not capable to raise its strength to the required level. A deficiency of elements, particularly that of carbon, may also lead to a lowering of the elementary composition and, therefore, the strength of welds made in such steel. This deficiency results from a mixing of the stronger metal supplied by the electrodes with the weaker one melted away from the sides of the groove, and the formation of a product, the properties of which will lie somewhere in between those of its components. It will prove acceptable as far as its tensile strength is concerned, if the amount of admixed metal was moderate or its chemical composition about normal; and it will prove unacceptable if the amount of metal liberated was high or its chemical deficiency particularly pronounced.

The extent to which the properties of the parent metal affect those of metal deposited by the electrodes is more pronounced than is generally assumed. This was brought out by an investigation in the course of which some electrodes, suspected of being deficient as far as the strength of metal deposited with them was concerned, were used in welding of grooves prepared from real and supposed 70,000 lb. minimum steel, respectively. Some of the results of this investigation were as follows:

Grade of Material	Yld. Pt.	Tens. Str.	El.	Red. A.	C	Mn	Mo
Real 70,000 lb. steel	64,000	74,000	29.0	52.0	0.110	0.650	0.320
Supposed 70,000 lb. steel	58,000	69,000	32.0	58.0	0.080	0.560	0.280

The difficulties that arise from the use of 70,000 lb. minimum steel with a low elementary composition and tensile strength could readily enough be eliminated if its users would insist on a greater margin of strength than was customary heretofore, or if they would decide to accept this steel only on the basis of tests carried out on coupons that have previously been given a treatment similar to the strain-relieving one If this attitude would become a general one, it would force the manufacturers to impart to their material an elementary composition which alone, and without the assistance of the work hardening from the rolling, would bring its strength to within the required level.

There can be no doubt that the steel manufacturers have attempted to accomplish this very thing more than once and that they gave it up just as often. They did so not because the introduction of more carbon into the steel increased their troubles and raised their cost, but because of the difficulties customers experienced in welding this material. Welds obtained in such material often tended to show more than the permissible amount of porosity and were so little ductile that they would open up in the course of welding, or shortly thereafter. Almost the same symptoms, only somewhat more pro-

* Metallurgical Engineer.

nounced, will occur when an attempt is made to join two pieces of tool steel by means of welding. In either case these difficulties result from a liberation of carbon from the parent metal and its absorption by the deposited one. The part of the carbon that is retained in its monoxide orm will give rise to an undue amount of gas-pockets, while the part that is retained in its elementary form will be followed by the formation of martensite and cracks. The latter are due mainly to the martensite's hardness and inability to resist the complicated stresses set-up in the course of welding and cooling. The formation of porosity and martensite may be prevented and that of the harmless pearlite enhanced, if the work in the course of welding is kept warm, the rate of cooling from the welding to normal temperature is artificially slowed down, and the welding is done in a manner that will remelt a minimum of parent metal. The first condition can be accomplished by keeping a gas jet burning underneath the seam until the work is ready to be placed into the strain relieving furnace; the second by positioning the work in such a manner that it will not be in the path of cold drafts, and the third, through the use of electrodes not greater than $^3/_{16}$ in. or $^1/_4$ in. in size and by depositing the metal from them in form of running beads rather than full width layers.

The 70,000 lb. minimum tensile steel is somewhat different and more touchy than the lower carbon medium strength one and must, therefore, be handled differently. The attempt of this article was to describe the most efficient and simplest way in which this can and is being done.

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WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

A Message

To the Members of the American Welding Society:

Whether it be a fault or a virtue, my impatience at delays and obstacles comes to me honestly. It is one of those "sins of the fathers visited upon even the third and fourth generations." My father was born near Belfast, Ireland, one hundred years ago the tenth of last July. Light heartedly, and I can imagine with that same unconquerable self confidence I see in my seventeen year old son, he slipped by the portals of his Scottish home and sailed for America to carve out his future, equipped only with his self confidence, a splendid physique and a spirit of perseverance seldom equalled. This is the prelude to my disappointment in not being able to tell you, as I had confidently expected to do by this time, that our program for the AMERICAN WELDING SOCIETY was well established and put into final form. Top executives of large industries have a way of flitting away from their headquarters and not being available. There is nothing to do except to curb ones impatience with whatever composure one can muster.

My year of administrative association with the Society is short at best, especially so, because the summer months are periods of semi hibernation for technical societies. The working year is in reality of but eight months. All the more need of drive and accomplishment in the fall, winter and spring seasons.

Our program is ambitious, calling for cooperation with other societies and that vast conglomerate industry in which welding plays a dominant part. We have made progress, real progress in these two months. We have rounded the third pole and we see the finish line ahead. Of real moment, we are running strong and within a very, very short time we will have hurdled all the barriers which two months ago loomed so ominously in our path.

Next month, I am sure, we can tell you the whole story and you will be thrilled with the work which your Ways and Means Committee, your Committee on Management, your Board and Headquarters' Staff have done.

This month I visited the Detroit and Northern New York sections. I had the opportunity to talk to the leaders of these groups and also to the sections as a whole. Their enthusiasm for building

Alfred E. Gibson

up their sections was heartening. Both have challenged every other group to match their percentage of increase in membership this year. They are giving every consideration to the presentation at their meetings of the most interesting subjects by outstanding speakers. The spirit shown, it wasn't put on for my benefit, it was real and sincere, certainly was encouraging.

You will be pleased to know that a new section has been started at Fort Peck, Montana. Three very energetic men, Messrs. Wolfe, Jefferson and Anderson attended the October convention and asked if they could not form a Section at Fort Peck where several hundred welders are employed on a huge government project. They start with 27 members, now just watch these boys go places!

Before long we will bring you similar stories of other new chapters, several of whom are ready to be organized as rapidly as we can give them the necessary support and help. This is all a part of our very definite program and is part of what I had in mind when I spoke of my impatience at delays.

At this period of the year, it is natural that one should pause long enough to give a friendly pat on the back, to let those with whom one works know that, in spite of the drive and competition in business, there is such a thing as sentiment in the battle for survival and progress. Just yesterday we slowed the wheels of management of our company long enough to entertain some three or four hundred members of the families of our workers. They came, wives of men I have worked with for nearly thirty years, to see their men at work, to see the operation of lathes and planers and boring mills, to see welding operations going on in the shop where their men folks have worked for years and years. I had met many of these women during the last quarter century. Probably all of them knew of me because most men find occasion at home to mention the "boss." As we chatted over coffee cups, they spoke of how much they appreciated seeing their men at work, of how big things are in the shop, wondered how one can possibly know what all those things in the plant are for. To me it was one of the real thrills of my more than twenty-five years of keeping the wheels going 'round.

So tonight I am filled with the Christmas spirit of good fellowship. I am sorry I was so sharp with one of our foremen yesterday, sorry even though he should have known better. After all, I, too, make mistakes and deserve some bawlings out I don't get.

Within a few days, the new year will be with us, a new year which I am certain will be epoch making for the AMERICAN WELDING SOCIETY. It will be so not alone in the real progress we are making but more so because it will see the setting in motion of a program backed by the active support of all our members, the results of which, we will all be proud.

My wish for a Happy and Prosperous New Year to all of you is genuine and sincere.

A. E. Gibson, President
(Dec. 19, 1936)

P. S. Are you getting your man, your new member?

See also Message from the *Chairman* of the *Membership Committee* Printed on the Inside Back Cover.

Lincoln Gold Medal

The president of the AMERICAN WELDING SOCIETY is pleased to announce the acceptance by the board of directors of the Society of a gold medal to be known as the "Lincoln Gold Medal," to be presented to the author of the best paper on any phase of welding published in the JOURNAL of the AMERICAN WELDING SOCIETY during the year October 1936 to October 1937.

A committee of three will be appointed to make the award, and the gold medal will be presented during the annual convention in October 1937.

The Society appreciates the generosity of Mr J. F. Lincoln, president of the Lincoln Electric Company, in offering this excellent award as a stimulus to the preparation of worth while contributions to the art of welding.

No paper will be considered for this award unless it is received by the editor of the JOURNAL before September 15, 1937.

The conditions of the award are:

First—Medal to be given through the AMERICAN WELDING SOCIETY.

Second—To be given to the writer of the paper which contributes most to the development and advancement of welding during 1937.

Third—This paper may be given before any Section of the AMERICAN WELDING SOCIETY or at the general Fall Meeting of the AMERICAN WELDING SOCIETY.

Fourth—No restrictions will be placed as to the subject matter, i.e., paper may be on electric arc, gas, resistance or any other form of welding coming under the scope of the AMERICAN WELDING SOCIETY.

Fifth—Decision as to the best paper to be made by a Committee selected by the President, such committee to be known as "The Lincoln Gold Medal Award Committee." The award to be made at the Annual Meeting which will probably be held in October of 1937.

Sixth—The committee in considering the award will consider the papers to be given at the 1937 Fall Meeting.

Obituary

SAMUEL WEISKOPF

Samuel C. Weiskopf, one of the nation's outstanding construction engineers, died at his home in St. Petersburg, Fla., on December 20th after a brief illness. His age was 76.

During his business career, he was identified prominently with the construction of many New York skyscrapers, including the Bankers' Trust, the Morgan bank and the Equitable buildings, the New York Stock Exchange and others. In Pittsburgh he was in charge of construction of the Mellon National Bank Building and other structures.

Mr. Weiskopf and his former partner, John W. Pickworth, were consulting engineers and designers of several of New York's large structures, including the American Radiator Building on West Fortieth Street. He was a pioneer in the construction of wind-braced skyscrapers and in the development of the process of electric welding.

He served on a joint committee of the American Society of Civil Engineers, AMERICAN WELDING SOCIETY and other engineering bodies which cooperated in exhaustive welding experiments.

Frank Pape McKibben

PRESIDENT
1932–1934

Resolved: that the SOCIETY through its Board of Directors offer to the family of

FRANK PAPE MCKIBBEN

its sincere sympathy in their recent loss. Able and effective *Teacher*, insistent upon high standards, both in work and in life, he made a permanent impress upon the three colleges where in turn he taught; *Designer* of many bridges, with beauty as well as strength his constant aim; a believer in welding even in its early days, he aided greatly in its development and in the educational work leading to its general acceptance in structural and other fields; member, director and *President* of the AMERICAN WELDING SOCIETY, he was ever wise in his judgments and generous in his help. His life was a life well worth living, and his memory one to be thought of with pride.

Dated December, Nineteen Hundred and Thirty-six

A. E. GIBSON, *President*
M. M. KELLY, *Secretary*

Translations

Through the courtesy of one of the cooperating companies of the Committee, there are available copies of translations "Internal Stresses in Welded Seams," by Prof. Mullenhoff, translated from *Elektroschweissung*, June 1935, pp. 103–108.

A limited number of copies of translation made by G. E. Claussen of "Progress in Welding During the First Six Months of 1936," by Wilhelm Lohman, translated from *Stahl und Eisen*, vol. 56, no. 36, Sept. 3, 1936, 1003–1006; No. 37, Sept. 10, 1032–1033.

A translation of "Atomic Hydrogen Welding (Langmuir Process)," by S. Sandelowsky (Berlin), appearing in *Z. VDI.*, vol. 75, pages 1361–1364 (1931), as translated by Prof. N. F. Ward of the University of California is now available.

Copies may be obtained by writing to Mr. W. Spraragen, Sec., Welding Research Committee, 33 West 39th Street, New York, N. Y.

Montana Section Organized

An organization meeting for the formation of the Section was held in Fort Peck, Montana, on the afternoon of November 22, 1936. The meeting was called to order by the Temporary Chairman, Wm. M. Galloway, in the Administration Building at Fort Peck.

On December 2, 1936, a second organization meeting was held and temporary bylaws adopted. The following officers were elected to hold office until April 1937.

Chairman—Henry F. C. Rumfelt
Vice-Chairman—Wm. M. Galloway
Secretary & Treasurer—Allen W. Bates
Meetings & Papers Committee—Chairman: T. B. Jefferson
Membership Committee—Chairman: W C. Anderson

It was agreed that regular meetings of the Section would be held on the first Wednesday of each month in the Administration Building in Fort Peck, Mont. The name of "Montana Section" was adopted.

Official notification granting the Society charter was made in a letter dated December 14th.

Annual Meeting

The Annual Meeting of the AMERICAN WELDING SOCIETY will be held in Atlantic City during the week of October 18th in conjunction with the National Metal Congress Exposition.

The Program Committee is already making its plans for an unusual meeting with the best technical papers available in the country. Suggestions for papers should be sent to the AMERICAN WELDING SOCIETY as early as possible in order that they may receive consideration by the committee for schedule on the program.

The James F. Lincoln Arc Welding Foundation

Spurred by a dual desire to stimulate scientific development in the arc welding field, and to honor the pioneer work of its president in promoting arc welding and perfecting and developing arc welding equipment and electrodes, The Lincoln Electric Company has just completed its long contemplated plans for establishing a Fund and Foundation to encourage study and research for benefit of the welding industry.

This new fund, which was voted by directors of the company at the turn of the

James F. Lincoln

year, has been named "The James F. Lincoln Arc Welding Foundation."

Principal direction of the Foundation's work will be given by Dr. E. E. Dreese, Chairman of the Department of Electrical Engineering of The Ohio State University.

Other trustees who will serve with Dr. Dreese on the Foundation are W. B. Stewart, distinguished member of the Cleveland Bar, and H. R. Harris, Vice-President of the Central United Bank of Cleveland.

Committee Appointments

The following committee appointments have been made to serve for the administrative year 1936–1937.

Membership:
A. F. Davis, *Chairman*
E. R. Benedict
L. C. Bibber
H. C. Boardman
H. R. Bullock
T. A. Canty
W. W. Carlton
O. H. Davenport
E. E. Dillman
A. S. Douglass
F. C. Emery
F. C. Fantz
A. E. Gaynor
A. E. Gibson
T. M. Jackson
J. H. Johnson
Lee Keim
H. J. Kicherer
T. R. Lawson
Milton Male
A. E. Marble
J. A. McCone
E. W. McCullough
E. E. Michaels
F. H. Miller
D. C. Myers
G. R. Raitt
H. O. T. Ridlon
F. V. Romig
R. L. Scollard
G. N. Sieger
C. E. Woodman

Meetings and Papers Committee:
E. Vom Steeg, *Chairman*
E. V. David
R. S. Donald
T. C. Fetherston
R. K. Hopkins
O. E. Hovey
M. Male
J. W. Sheffer
M. L. Smith
W. Spraragen, *Secretary*

Subcommittee on Publications:
A. G. Oehler, *Chairman*

Subcommittee on Program:
E. V. David, *Chairman*

Subcommittee on Publicity:
Merritt L. Smith, *Chairman*

Manufacturers Committee:
J. B. Tinnon, *Chairman*
L. R. Berkeley (E. W. Kronbach, alternate)
W. P. Burglund (T. C. Fetherston, alternate)
F. Connell
A. F. Davis
J. J. Flaherty
A. E. Gaynor
K. L. Hansen
O. L. Howland
L. D. Meeker
W. W. Reddie
C. E. Swift
G. Van Alstyne
H. A. Woofter

Finance Committee:
C. A. McCune, *Chairman*
F. M. Farmer
D. S. Jacobus
M. M. Kelly

Board of Trustees—Miller Memorial Medal:
C. A. Adams, *Chairman*
C. J. Holslag
H. L. Whittemore

SECTION ACTIVITIES

BOSTON

Approximately 600 people attended the December 17th meeting of this Section at the Watertown Arsenal. This meeting was a joint meeting with the Boston Section A. S. M. E. and the Plant Engineers Club.

The afternoon session started at 2:00 P.M. and consisted of a plant visitation until 4:30. Dinner was served at 6:00 P.M., and at the evening session two interesting papers were presented.

Lt. Colonel J. Kirk spoke on "Machining Gun Tubes from Cylindrical Steel Castings." Mr. W. L. Warner, Metallurgical Engineer, spoke on "Welding of Low Alloy High Tensile Steels." Both talks were illustrated. The speakers were introduced by Colonel Jenks, Commanding Officer of the Arsenal, through whose courtesy this very successful meeting was arranged.

CHICAGO

A joint meeting of the Chicago Section and the Maintenance-of-Way Club of Chicago was held on December 14th at the Auditorium Hotel. "Welding and Heat-Treating Rail Ends"—By the Gas Process, was presented by Armstrong Chinn, of the Chicago & Alton Railroad, Chicago; By the Electric Process, by C. B. Brownson, of the New York Central Lines, New York City. "Welding Open-Hearth and Manganese Frogs" was presented by S. E. Tracy of the C. B. & Q. Railroad, Chicago.

DETROIT

The Detroit Section has plans well under way for the first two meetings of this year. The first meeting will be held early in February and will be devoted to the applications of electric resistance welding in the automotive industry. The second meeting, to be held in March, will be devoted to the applications of fusion welding in the tool and die industry. Both subjects are of great interest to many people in the Detroit area and it is hoped to set some new meeting attendance records.

LOS ANGELES

The regular meeting was held December 3rd at the Los Angeles Chamber of Commerce Building with 80 members and guests present. Dinner was served at 6:30 P.M., after which the meeting was called to order by Chairman Blake. Guests were introduced and minutes of the previous meeting read and approved.

The first speaker was Mr. W. C. Maine, Field Engineer, Youngstown Sheet and Tube Co. He presented an extremely interesting talk, illustrated by slides, on "Welding of Oil Well Casing."

The second speaker, Mr. Turner C. Smith, Regional Vice-President of the AMERICAN WELDING SOCIETY, gave a very interesting talk covering his attendance at committee and other meetings at the AMERICAN WELDING SOCIETY convention in Cleveland.

The program Chairman announced that the next meeting will be in January.

MARYLAND

The following schedule is the program for the Maryland Section:

January 15th—Showing of Republic's Enduro Movie and Lecture by T. R. Lichtenwalter.

February 19th—Lecture by J. F. Lincoln of the Lincoln Electric Co.

March 19th—Talk on Metal Coating by Mr. Stewart of the Naval Engineering Experiment Station.

April 16th—Everett Chapman of Lukenweld, Inc., will talk on control of deflection in welding.

MILWAUKEE

The December meeting of the Milwaukee Section was held on the 9th at the Milwaukee School of Engineering. Mr. C. L. Pfeiffer, Electrical Engineer of the Western Electric Co. spoke on "Principles of Resistance Welding and Construction Features of Special Resistance Welding Machines."

NEW YORK

A joint meeting of the New York Sections of the A. W. S. and A. S. M. E. was held on the 13th of January, on the subject "Non Destructive Testing of Welded Joints and Machine Parts." Mr. Ancel St. John of the St. John X-ray Service, spoke on "Radiographic Inspection of Welded Steel Plate Construction;" Mr. R. T. Cavanagh of the Fidelity & Casualty Co. of New York; Mr. G. E. Rathbone also of the Fidelity & Casualty Co. of New York, spoke on "The Detection of Fatigue Cracks by the Magnaflux Method."

The following are the coming meetings of the Section:

March 2, 1937—Discussion of Bridge Welding Code.

April 13, 1937—Shipbuilding.

April 19, 1937—Joint meeting with A. S. M. E.—Stresses in Welds and Their Elimination.

May 11, 1937—Subject to be announced.

PHILADELPHIA

The January 18th meeting of the Philadelphia Section will be devoted to "Railroad Night."

PITTSBURGH

A joint meeting of the Pittsburgh Section and the Engineers Society of Western Pennsylvania will be held in the Cardinal Room, William Penn Hotel, Wednesday night, January 27th. Mr. A. E. Gibson, *President* of the AMERICAN WELDING SOCIETY and Vice-President of the Wellman Engineering Co., will be the principal speaker. Mr. Gibson's address will be on "Why We Weld" and will cover the use of welding in the building of their equipment, much of which goes into steel making plants.

There will also be a short talk by Mr. A. E. Einig, General Manager of Motch and Merryweath Co. on "Industrial Conditions in Russia."

A record turnout is expected.

SAN FRANCISCO

The final meeting of the year of the San Francisco Section of the AMERICAN WELDING SOCIETY was held at Capri's Italian Restaurant in Oakland on Friday, December 18th. The meeting was in the nature of a pre-Christmas get-together as well as a formal meeting.

"Tom and Jerrys" were served prior to the dinner which was served at 7 P.M. to 33 members and guests.

Following dinner, the regular meeting was called to order by Chairman Mathy, with 42 present.

Chairman Mathy then called on Mr. L. C. Henderson, District Manager for the Lincoln Electric Company, who spoke on the subject "Arc Welding of Low-Alloy High-Tensile Metals."

Following this Mr. C. S. Smith, District Manager for the Linde Air Products Company, spoke on the subject "Oxy-acetylene Welding of Alloy Steels."

These talks and papers were very well received by all present.

Following this Chairman Mathy announced the personnel of the Committee for study of the State of California requirements for testing welds and welders and announced that a meeting of this committee was being held immediately following adjournment of the regular meeting.

EMPLOYMENT SERVICE BULLETIN

POSITION VACANT

V-73. Welding shop desires Sales Engineer to procure welding work. This shop capable of doing industrial and all types of repair welding using all processes.

SERVICES AVAILABLE

A-234. Welding Engineer. Technical graduate, eight years in arc welding, development, design, research and commercial welding applications. Six and one-half years with one of the largest manufacturers of arc welding equipment in the world.

SETS OF BOUND VOLUMES OF JOURNAL

In order to provide some of the new members of the SOCIETY with an opportunity to complete their library on Current Welding Literature, the AMERICAN WELDING SOCIETY is offering to these new members an opportunity to purchase the last six bound volumes for years 1930, 1931, 1932, 1933, 1934, 1935 at $25.00 a set. The price to non-members for individual volumes is $6.50 and for the set $30.00.

Each bound volume contains a Subject and Authors' Index and is bound in attractive imitation black leather covers. The set probably includes the most important welding information available in the literature.

Important Notice!

All members of the American Welding Society, are invited to attend the Welding Session of the A. I. E. E. Winter Convention, Thursday, Jan. 28th, Engineering Societies Building, Room 1, 5th Floor, 2 P.M.

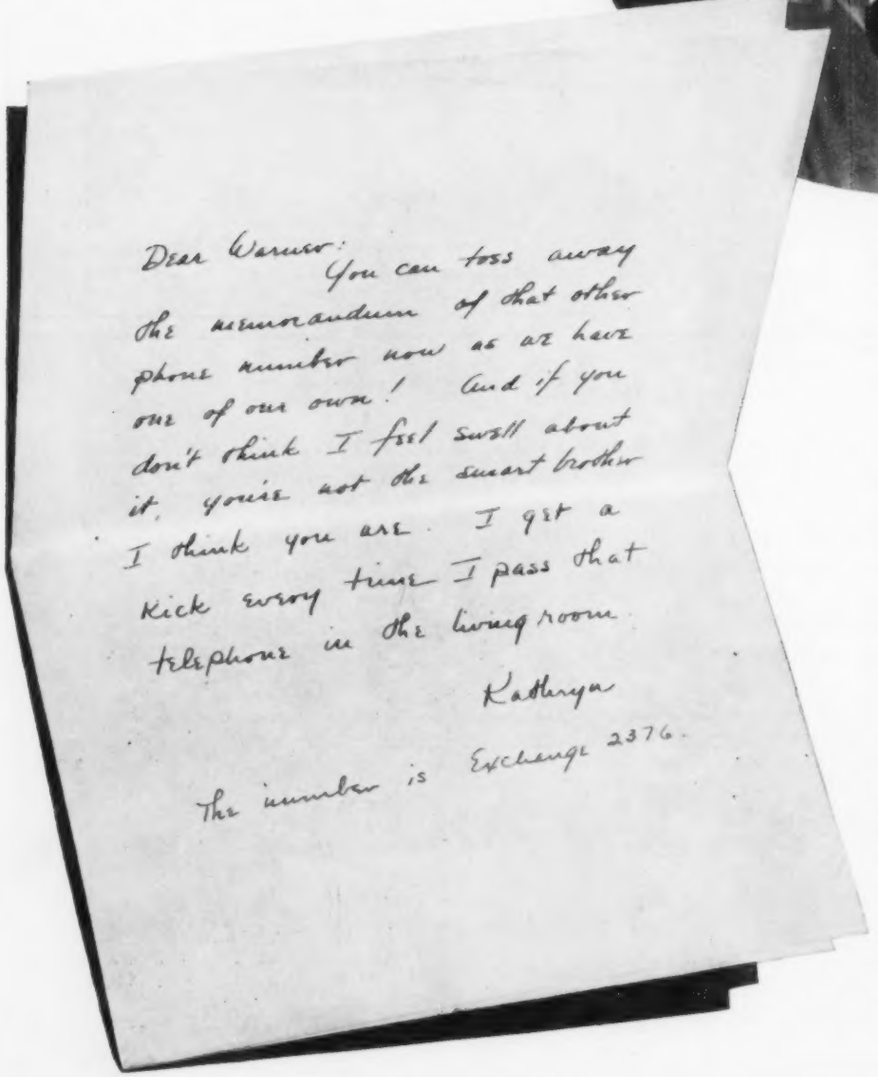
Demonstrations of the Fundamental Phenomena of the Electric Arc—G. E. Research Laboratory and the Resistance Welding Circuit, C. L. Pfeiffer, Western Electric Co.

Also there will be an inspection trip to the plant of the M. W. Kellogg Company on Tuesday, Jan. 26th.

1936 BOUND VOLUME

Bound Volumes of the JOURNAL of the Society for the year 1936 are now available with imitation black leather covers. Contains a wealth of information on the latest developments in welding. Also contains Subject and Authors' Index. Price, $5.00 plus postage to members; $6.50 to non-members.

A Happy New Year for *Kathryn*


Dear Warner: You can toss away the memorandum of that other phone number now as we have one of our own! And if you don't think I feel swell about it, you're not the smart brother I think you are. I get a kick every time I pass that telephone in the living room.
Kathryn
The number is Exchange 2376.

THAT'S a real letter—written by a real Kathryn—to her brother. You can read her happiness in every line. She's mighty glad to have the telephone back.

And so are a great many other men and women these days. About 850,000 new telephones have been installed in the past year.

That means more than just having a telephone within reach. It means keeping the family circle unbroken—contacts with people—gaiety, solace, friendship. It means greater comfort, security; quick aid in emergency.

Whether it be the grand house on the hill or the cottage in the valley, there's more happiness for everybody when there's a telephone in the home.

The Bell System employs more men and women than any other business organization in the United States. The total is now close to 300,000. Good business for the telephone company is a sign of good business throughout the country.

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